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ABSTRACT

The proceedings of the International Conference on Energy Alternatives and Risk Education contains papers which examine science teaching in relation to societal aspects of risk assessment. A challenge for the conference was to show how science education can help students learn the concepts of acceptable and unacceptable risks, leading to rational decision making. Energy education was chosen as a vehicle for answering this challenge. The proceedings are divided into sections on energy education, nuclear education, and risk education. Some of the papers presented include: "Energy Change, Difference and Danger" (Jon Ogborn); "Energy Education for Non-science Majors" (Joseph R. Priest, William H. Rauckhorst); "Microcomputer in Teaching about Energy Conservation" (Jozefina Turlo, Zygmund Turlo); "Student Energy Research Competition" (John FitzGibbons, Joseph Drenchko); "Training Atomic Energy, Aimed at Teachers" (M. Hiroshe et al.); "Nuclear Teacher Training in Hungary" (Kate Papp); "The Public Acceptance of Nuclear Power" (Philippe Berthelot); "Why in the World Should We Teach Statistics?" (Ed Jacobsen); "Risk Perception Studies in Schools" (Joan Solomon); "Acid Rain Monitoring in Schools" (I. Hobinka, M. Riedel, B. Javorszky); and "The Business of Future" (E. Leonard Jossem). The book includes summaries of 15 workshops, and a list of conference participants. (LZ)

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ENERGY ALTERNATIVES / RISK EDUCATION I.

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ENERGY EDUCATION

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ENERGY EDUCATION

Volume I of the Proceedings of the International Conference on

ENERGY ALTERNATIVES / RISK EDUCATION

held at the Lake Balaton in Hungary, 7–13 September, 1989

edited
by
George Marx
Department of Atomic Physics,
Eötvös University, Budapest

National Centre for Educational Technology
Veszprém, Hungary, 1989

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ELNÖKE

WELCOME

F. Bruno Straub
president of Hungary

LADIES and GENTLEMEN, Distinguished Guests!

I was looking forward with great interest to meet you at this international conference. Science teaching in relation to societal aspects of risk assesement is indeed an important contemporary problem.

Unfortunately, unforseen other programme which I have to attend in Budapest, are preventing me from attending your conference. Please, accept my apologies.

The sum of your discussions will interest all scientists who feel a responsibility toward their Societies. Having spent a lifetime with research in biochemistry, lately I met several times situations in which I had to form my opinion on controversial questions concerning e.g. the risk assesment of new technologies and decisions concerning question of priorities in fighting environmental pollution.

I believe, there are many controversial questions, where a simple yes or no answer cannot be given. For one thing: cultural background and tradition lead different population groups to assign different values in risk assesment.

Closer to the central issues which you will be discussing, is the problem which our generation has started to consider, what damage we are doing to the life of mankind during the next centuries?

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In our country, right now a heated discussion is developing about a low level radiactire waste disposal site. It obviously has to contain the waste for a few centuries. The trouble, I believe stems from the fact that the issue was not treated in a complex way. It is my conclusion, that if we want to educate a public, which has to make good decisions for the future, this teaching has to be a complex one.

I am sure, that your contributions will help us in our own efforts in applying your results for the benefit of our progress. And, I wish you a pleasant sojourn in Hungary.

F.Brunó Straub

GREETINGS

Frederico Mayor
director-general of UNESCO

I would like to express UNESCO's sincere gratitude to the Hungarian Ministry of Education, the Academy of Sciences, Hungarian Atomic Energy Commission and other institutes, both national and international, for sponsoring this meeting. The professional input from GIREP, IUPAP-ICPE, ICSU-CTS and the organization by the Roland Eötvös University has created us a stimulating and forward-looking meeting. We must thank the participants who have come from far and near to share their ideas and experiences with us.

During the 1980s, science and technology have played an important role in economic and social development. The lives of all societies are shaped by the rapid application of basic scientific research. The resulting progress is extremely uneven from region to region and country to country. The between country differences in energy consumption illustrate this well. UNESCO has been called upon to contribute to the development of science which may lead to sustainable development of all nations. At the same time, Member States, in expressing their concern at the degradation of our environment, request UNESCO to mobilize world action in science and education for the protection of the environment. Many choices are available, yet the decisions we must make are based upon incomplete or uncertain data. Also, many of our choices contain a certain risk of adverse effects. We collectively make decisions about the choice of atomic or coal power for electricity generation with their respective risks of nuclear discharge or acid rain, of residuals of pesticides, hormones, fertilizers and chemical additives in foods, of maximum allowable adverse side-effects of medicines, etc. We must balance fear and opportunity by understanding the risks of alternatives. Most people are poor at distinguishing between big and small risks.

One cannot live in perfect security, so we should understand the probabilities well enough to know the relative importance of the dangers. Traditional science courses teach us to think in certainty, even when it is unwarranted. Educating for risk must be interdisciplinary because the sources of risk can be scientific, legal, financial, social, technological, political, or any combination. All citizens should learn the balancing of risk and benefit. Thus all should be comfortable in the presence of statistics.

This conference is thus timely. Hungary has been quick to identify areas in science education needing international co-operation, and Balaton has become a world centre for science education, as proven in their previous meetings about Entropy, Chaos, Microcomputers.

A challenge for the conference is to show the way how science education can help students learn the concepts of acceptable and unacceptable risks and to rational decision making. The vehicle of energy should take us there. I look forward to the ideas to develop. This is our common goal.

(presented by Ed Jacobsen, Mathematics Education Programme Specialist, Division of Science, Technical and Environmental Education, UNESCO)

ENERGY, ENVIRONMENT, EDUCATION

John L. Lewis, Committee of Teaching of Science at ICSU
Pump College, Malvern
Worcestershire WR13 6DX, United Kingdom

Ladies and Gentlemen, you have done me a very great honour inviting me to give this opening address. It is sad that the President cannot be with us as he is a former President of the International Council of Scientific Unions and I bring greetings from their Committee on the Teaching of Science (ICSU-CTS) wishing you success during what promises to be a most interesting conference.

I must start by saying what a pleasure it is to be here in this lovely place for another enterprise organised by George Marx. It is always interesting to be involved in anything to do with that remarkable man - and I suppose it is a characteristic of physics education conferences that they are always fun. A very distinguished physicist from a European country at a recent science education meeting commented, apparently with surprise, on the friendly atmosphere: he suggested that in many academic meetings there is a tension as ideas come into conflict, whereas in education conferences of this kind we were all striving together towards the common goal of finding ways to provide better education. And this is probably why a mere schoolmaster, such as I am, can feel at home in them; I do not have to prove anything.

Education

To begin, I hope you will allow me to change the title I have been given by putting the three Es in alphabetical order so that Education comes first and I can start with that as it seems appropriate in this opening talk to begin with a broad look at education. Considerations in my own country[1] have led to the formulation of the following as the areas of learning and experience which should feature in the rounded education of all children (listed here alphabetically):

aesthetic and creative;
human and social;
linguistic and literary;
mathematical;
moral;
physical;
scientific.

Of course these are not discrete elements to be taught separately, and individual subjects contribute to a number of different areas. Environmental education, for example, impinges on many of them. I do not want to enlarge further on this, but

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[1]. For further details see *The Curriculum from 5 to 16*, published by the Department of Education and Science, London. 1985. ISBN 011-270568-5

I hope this wider aspect of education might be at the back of our thoughts during the coming week.

This is only one perspective. Another, which complements it, is concerned with four elements of learning, namely:

knowledge,
concepts,
skills,
attitudes.

Knowledge

One of the troubles with knowledge is that there is so much of it, especially knowledge about physics which we think is intrinsically interesting and of potential use, but the result is that syllabuses are often dreadfully overladen with factual content.

I have had the privilege recently of spending a month in the Republic of China. What charming people they are, struggling to improve their physics education, but perhaps their biggest problem is the size of their syllabus. It has grown and grown and I could see little evidence of anything having been cut out from what might have been appropriate in the 1930s with more and more modern physics and applications added on top. The result is that the teaching is dominated by factual knowledge as are their examinations. We have all been guilty of this in the past and let us hope their efforts to change things will be successful.

My point is that it is essential to be highly selective when deciding what is to be taught. Topics should be chosen as necessary ingredients of areas of learning and experience or because they have important contributions to make to the the development of concepts, skills and attitudes, and teachers should reject content which contributes relatively little to pupils' education. At one time we were told we must keep a lot of geometrical optics in the syllabus "because many of our students want to be doctors"; but how many pathologists looking into a microscope ever think of

$$\mu/v - 1/u = (\mu-1)/R$$

As I have mentioned to some of you before, I was brought up when science teaching consisted of water-tight independent compartments - heat, light, magnetism, electricity, properties of matter, sound (when you had time for it). We owe much in England to Eric Rogers who provided us with a programme which showed to the pupils how the topics formed a fabric of knowledge, where a topic studied in one place is seen to have relevance elsewhere, thereby helping pupils to see its significance.

I can remember Professor Amos de Shalit saying: "The fact that we have been very thoroughly exposed to the law of Archimedes does not mean that our children have to go through this experience as well". And there is something else to be learned: too often we expose children to topics before they have the necessary ability to appreciate them; for example, all those density calculations, which took much time with younger students, become trivial when they are older.

There is another factor which has an adverse effect: too often compilers of syllabuses look on primary education as the foundation for secondary education, which in turn is the foundation for tertiary education and so on. I suspect that George Marx would always have come out on top whatever education he was given. Fortunately this is now widely appreciated and all of us here would agree that each level of education has to be seen as an end in itself.

Examinations

And before I leave knowledge, I must refer to another aspect which has the profoundest influence on what is taught: examinations. I have a dislike for multiple choice questions because so often (though I agree not always) they rely heavily on factual knowledge. I was brought up on some terrible questions which I am almost ashamed to show you:

1. Define *specific heat, latent heat, water equivalent of calorimeter.*

   250 gm of lead at 90° are dropped into a copper calorimeter weighing 100 gm containing a mixture of 60 gm of water at 0°C and 5 gm of ice. The whole is stirred rapidly. What will the final temperature of the mixture be?

2. What do you understand by the terms *energy* and *momentum*? Explain the difference between potential and kinetic energy. What is the principle of conservation of momentum?

   The hammer of a pile driver has a mass of 10 cwt and the pile a mass of 2 cwt. When the hammer falls a vertical distance of 9 ft before striking the pile, the latter is driven a distance of 6 in into the ground. Assuming the hammer does not rebound and the mean resistance of the ground remains the same, how far into the ground would the pile be driven if the hammer fell a distance of 16 ft?

I hope they show why so much of my time was spent learning definitions and memorising formula – and how ghastly life was before we moved to metric units!

But if I show you bad questions, I must also show what I consider a good one. We must start by asking the students to read the following and then answer the questions:

There is a 400 m difference in the levels of the Mediterranean and the Dead Sea. It is proposed to connect the two by a pipeline in which water from the Mediterranean will flow into the Dead Sea and in the process will operate a hydroelectric power station. In order that the water level in the Dead Sea should not rise appreciably, it will be necessary to limit the quantity of water which flows into the Dead Sea each year. The amount of water should equal the amount of water lost by evaporation each year. In the past 1660×10^6 m^3 of water flowed into it per year from the River Jordan keeping the water level constant. Because of irrigation schemes this supply is almost cut off.

(a) In order that the system shall work, why is it necessary for there to be a difference between the water level in the Dead Sea and the Mediterranean?

(b) How is it possible for a flow of water to produce electric power?

(c) Explain in terms of molecules why the water in the Dead Sea evaporates?

(d) What difference, if any, will it make if the water evaporating from the Dead Sea is water from the Mediterranean rather than fresh water from the River Jordan?

(e) Assuming the density of water is 10^3 kg/m^3, calculate the potential energy transferred in a year.

(f) Assuming that the power station is 40% efficient, deduce what power will be generated in megawatts.

I like that question, which is really a straight forward energy conversion question, because it relates the physics to a real life situation and at the same time encourages thought about some basic things. No doubt many bright ideas will be developed this week and I would be delighted if perhaps someone thought how such items can be turned into examination questions.

Understanding of concepts and the importance of experiments

The appreciation of concepts is as important as the acquisition of knowledge. Precise definitions are not enough and concepts, such as acceleration, need to be developed on the basis of experience and one of the most difficult of all concepts is energy, perhaps it is even more difficult than entropy. No doubt we will discuss this during the week.

I was introduced to energy through a series of mathematical equations, which gave me no feel for the concept. We now prefer an approach through showing what energy will do, perhaps a series of experiments showing energy conversions from one form to another—and you will notice my reference here to experiments, as of course it is through experiments that pupils come to understanding.

The wall of the Botany Laboratory in the Botanical Gardens of Oxford University quotes:

> SINE EXPERIENTIA NIHIL SUFFICIENTER SCIRI POTEST
> (or 'Without experience one cannot understand anything).

I like those experiments which show energy conversions from one form to another and which were extensively used in the Nuffield projects: a battery which drives a motor which lifts a weight and then the falling weight drives the motor in reverse as a dynamo and a lamp is lit. Or the water driving a turbine which drives a motor to light a lamp, and then the process is reversed with the turbine operated as a pump to raise water from a lower level to a higher one.

At a more sophisticated stage, we can consider what is reversible and what is not. It always makes an impact to show a film of a man dropping a brick and then to run the film in reverse so that the brick rises from the floor - and thus bringing us to some statistical mechanics.

Then there is that other lovely experiment which I tried to show in Munich at the last ICPE meeting: the thermopile which drove the motor when I poured boiling water into one side - then we tried to make it go faster by pouring in more hot water on the other side and it stopped. Finally, we poured away the water and I tried to get Paul Black to drive it on cold Munchen beer, poured on one side while the other remained hot, but our efforts to use beer as the fuel failed because of all the froth! At least it was a good lesson in the need to test every detail before demonstrating!

All these experiments are well known and I need not refer further to them. But before I leave the concept of energy, a favourite of mine to see whether people have a feel for the size of units is to pose the following multiple choice question:

> Imagine that a car of mass 1000 kg is given gravitational potential energy equal to one unit of electrical energy (1 kWh). The car rises a distance most nearly equal to

A	1 cm
B	1 metre
C	4 metres
D	40 metres
E	400 metres

The result always surprises and if the same energy went to kinetic energy the speed acquired is about 300 km/hr.

Development of skills

Another element in the learning process is the acquisition of skills. Such skills need to be developed through a variety of activities and these will include skills of communication and observation, practical skills, and of course creative and imaginative skills. In this development of skills, pupils must be allowed to make mistakes, above all the teacher must resist the temptation to give the 'right' answer. And there are also personal and social skills to be learnt: learning to be cooperative in a variety of ways is beginning to pervade our science and technology teaching these days.

Attitudes and public understanding

This brings me to the last of these elements of learning, namely attitudes. Here I am very concerned as we still have much to learn and I have hopes that this conference will help. This is associated with the public understanding of science, or I should say the lack of it. With sadness I read the following in a paper published by the Science Council of Canada:

> "Even informed public debate is not possible because of the general indifference and ignorance of the social effects of science and technology."

and

> "The issue now is no longer that students do not know what 'science' is, nor that they are failing to learn enough of it, but rather that they do not come to appreciate its personal, social and national relevance."

It has been my habit (often to the embarrassment of people with me) to ask whoever waits on me in a restaurant whether they studied physics at school I am afraid too often I get very depressing answers. Last year in the Ratskeller in the centre of Munich, the young lady who served me said she had enjoyed it at school, but had given it up to study social science at the university "because physics had nothing to do with living". What a terrible indictment of our teaching!

It is encouraging however that so many of our countries are now giving more attention to the relationship between science and society in their teaching, not least through the consideration of contemporary problems. I am proud of the contributions which have been made in this direction in my own country, starting from the Science in Society project, leading on now to individual units[2] which can be fed into any teaching programme. Speaking as a teacher, the need is always for more and more resource material and one hopes that during the coming week there will be new contributions.

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[2] The ten volumes of SATIS units, containing in all a hundred short teaching units for students in the age range 14-16 are available from the Association for Science Education, College Lane, Hatfield AL10 9AA, UK. These are now being extended into further units for both older and younger students.

And this is the moment when I should draw the attention of anyone who has not yet got copies to the nine volumes which came out of the Bangalore Conference on 'Science and Technology Education and Future Human Needs' on the themes Health, Food and Agriculture, Energy Resources, Land, Water and Mineral Resources, Industry and Technology, The Environment and Education, Information Transfer, Ethics and Social Responsibility, a remarkable collection of resources from all parts of the world.[3]

I always think you can learn something about public understanding of science from responses to examination papers. Perhaps you will allow me to quote my latest batch:

> ENERGY IS THE BEST ALL ROUND FUEL
>
> HYDRO-ELECTRICITY IS THE SAFEST FORM OF ELECTRICITY BECAUSE IT IS MAINLY WATER
>
> PEOPLE PREFER HYDRO-ELECTRICITY BECAUSE THEY DO NOT HAVE TO HAVE PILES
>
> LESS COAL IS MINED BECAUSE PEOPLE PREFER TO USE ELECTRICITY
>
> NUCLEAR ELECTRICITY IS A VERY DANGEROUS FORM OF ELECTRICITY TO CONTROL
>
> UNFORTUNATELY GAS IS FLAMMABLE;
> GAS IS DANGEROUS IF INTOXICATED;
> GAS IS THE CHEAPEST FORM OF ELECTRICITY.
>
> LAND FOR HUNDREDS OF THOUSANDS OF KILOMETRES FROM CHERNOBYL HAS BEEN AFFECTED.
>
> ACCIDENTS CAUSE DEATH WHICH IT TAKES A LONG TIME TO RECOVER FROM.
>
> WE NEED TO SAVE FUEL, SO THE GOVERNMENT HAS PASSED A LAW OF CONSERVATION OF ENERGY

These reveal that we still have a long way to go in educating people!

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[3]. Nine volumes on *Science and Technology Education and Future Human Needs*, published by the ICSU Press and obtainable from Pergamon Press, Headington Hill, Oxford UK.

Alternative energy sources: decision-making exercises

It would not be appropriate in this opening talk to say much about alternative energy sources as there will be major contributions about them during the coming week, though I hope the wide spectrum of energy use in different countries throughout the world will be constantly in our minds and that we will concern ourselves with both ends of that spectrum.

However I will mention one aspect of the teaching of which I have some experience. Reference was made earlier to the importance of communication skills, as well as personal and social skills and the need to learn to be cooperative, as well as the importance of showing the relevance of what we teach to the world in which we live. As Amos de Shalit said, shortly before he died, "in our teaching, we should provide help in decision-making". Decision-making exercises have much to contribute.

One such exercise which I have used extensively is the Power Station game. It is imagined that a power station has to be built in a region of a country. Having learnt about the production of electricity from coal, oil and nuclear fuel, the students are divided into three groups. Each is given the task of examining the feasibility of building the power station using one of the fuels. They also have to choose one of six possible sites for their station and, in so doing, take into account technical, economic, social and environmental factors. Then each group puts forward a detailed case for its particular power station. It becomes a competition and that always leads to interesting teaching.

Another such decision-making exercise is the Alternative Energy Project. This is based on a fictitious island off the British Isles, the Isle of Elaskay, but it could easily be adapted to most national settings. It is assumed the island wishes to meet its future electricity needs by making use of its natural energy resources. It involves investigating the technical and economic feasibility of exploiting the various sources available on the island: peat, solar energy, wind energy, tidal energy, hydroelectric power. And then devising a rolling programme for meeting Elaskay's needs over the next 50 years.

The students are first divided into five working groups, each group considers one of the energy sources and in due course presents their findings to the class as a whole, giving information on:

- a proposed site;
- the expected annual electrical output;
- the peak generating capacity;
- the time needed to build it;
- the expected operational life.

A chart of the relevant information is produced.

The final stage of the project should be devoted to the development of a cost-effective and environmentally-acceptable rolling programme for meeting the future electricity needs. The final discussion on the viability of the scheme for the Isle of Elaskay provides an opportunity to discuss whether similar resources can help to solve energy problems elsewhere in the world.

Both these projects are always popular with students and one of the educational advantages is that the students do much of the digging out of information themselves: I find this infinitely better than my boring them with tedious lectures on different energy sources. It involves both physics and mathematics (there is plenty of quantitative work), it asks questions about the environment, it concerns a variety of alternative energy sources (and another version in another country could bring in other sources as well), it develops a variety of communication and personal skills - and it is fun. I look forward to this week as we shall experience a number of such exercises.

Risk

Finally I come to the question of risk – and it would be unwise for a mere schoolmaster to say much about this in view of the distinguished experts speaking later. But there are one or two obvious things which might be worth saying at this stage.

First, we should remember that radiation does not produce any extra deaths: all it may do is to change the time and nature of our dying. The one certainty is that we will all die: the risk is 100%.

Secondly, every activity we do is accompanied by risk - whether it be working in Bhopal, flying to Hungary, travelling by car or merely living in our own homes. Of course the risk in rock climbing - about 1 in 200 per year - is well known and anyone indulging in it knows the risk he or she is taking. The risk is obvious and precise. The trouble with nuclear radiation is that it cannot be seen or felt, and in consequence it generates fear.

Thirdly, one of the biggest challenges to us is to promote public understanding. Far too many people relate a nuclear power station to an atomic bomb and somehow we have to change that attitude.

To see things in perspective, it is important to remember that, terrible as the accident at Chernobyl was, it resulted in only 29 immediate deaths, substantially less than deaths from most air accidents. However, the immediate response to that is: what about the long term effects? That is where it is necessary to consider in more detail what radiation we receive and what are the biological effects of radiation.

We are all subjected to radiation and the average annual dose for each individual in the UK from radiation of natural origin is

cosmic radiation	250 µSv
terrestial radiation	350 µSv
radon decay products	1200 µSv
other internal radiation	400µSv

which gives a total of 2200 µSv or just over 2 mSv per year. (These figures come from our National Radiological Protection Board, a board independent of all other agencies, as is the International Commission for Radiological Protection.)

The average dose from other sources is:

medical	300 µSv
weapons fallout	10 µSv
discharges to the environment	1 µSv
occupational exposure	5 µSv
miscellaneous	10 µSv

It is worth also reminding ourselves that because of the effect of cosmic rays at high altitudes, the extra dose incurred by a flight from London to Budapest is about 15 µSv and for a flight across the Atlantic about 50 µSv. I will still fly home at the end of the conference!

Furthermore, we are all radioactive, for example from the amount of radioactive potassium inside us. The cells of our bodies are continually affected - of the order of a million million events every hour.

Cells are particularly sensitive to radiation: that is why malignant cancerous cells are subjected to radiation in an attempt to destroy them. Fortunately our bodies have an ability to repair damage to normal cells when they are subjected to radiation in relatively small doses such as those listed above. But it is important to draw a distinction between the two types of effect produced by radiation.

First, there are the stochastic effects (random effects) and these can be caused by low levels of radiation. Most damaged cells will be repaired, but this may not happen and there may be a delayed effect over a considerable period of time. One current theory of cancer induction is that the malignant cancer derives from faulty repair of a damaged cell. Whether or not this happens is a matter of chance - and hence the stochastic or random nature. Such delayed effects are entirely different from the effects due to an initial heavy dose.

Small doses have no effects other than the stochastic ones and there is even a theory that small doses may be beneficial. But heavy doses beyond a certain threshold damage so many cells that it is beyond the capacity of the system to repair the damage. A dose of

10 Sv or more delivered to a substantial part of the body within a few minutes is invariably fatal. A single dose of 4 Sv will result in a 1 in 2 chance of death, but the same dose applied over a year would certainly be tolerated as far as early effects are concerned, but if some cells were not properly repaired there would be an increased risk of dying of cancer (the stochastic effect).

For short term effects, it is possible to talk in terms of risk as a chance of 1 in 2, as it is possible to talk in terms of 1 in 200 for rock climbing. This is less appropriate, just as it is inappropriate to talk of average values, for the delayed effects (though it is often done and will no doubt be done during this conference). It may be better to express the risk differently, for example, if 10,000 people receive a dose of 80 mSv, 20 people may lose 10 years of their life, but 9980 will experience no effect at all. Expressed as an average this is about 3 hours per person.

I should briefly refer to clusters which have caused great concern in Britain. There have been statistically significant clusters of child leukaemia around two nuclear installations, Sellafield and Dounreay. These remain a mystery as careful monitoring in the area shows that the radiation which originates from the nuclear plant is a small fraction of the normal natural background. Furthermore there are similar clusters for places such as Gateshead, which are nowhere near a nuclear installation. The cause of these clusters continues to be sought.

Lastly, I come to Chernobyl. Of course, this will rightly be considered in detail during this conference. But I would like to show you what has been its effect in the UK (see Fig 1). The contribution to the average dose received is small indeed compared with the dose received from other sources. We need to be far more concerned about the radon concentration in our homes, especially in some parts of the UK - as of course we need to be concerned about the pollutant effects of burning fossil fuels and the CO_2 effects, which will also be considered later in this conference.

Statistics

I have little doubt that statistics will be quoted at length in the conference and young people need to be made aware of the different ways in which information can be presented. Fig 2, for example, shows how the same population figures can be plotted differently to give apparently different impressions by suppressing the origin. Changing the axes or plotting percentages instead of actual figures can again distort the picture and there is always the danger of extrapolation, as illustrated in Fig 3.

My plea is that these things should be stressed as part of our teaching, especially when we are concerned with some of the topics of this conference.

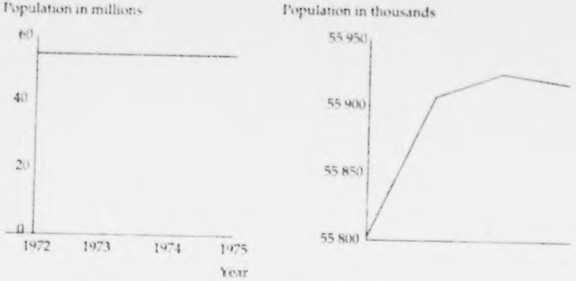

Fig 2: the same figures can be plotted differently to give a totally different effect by suppressing the origin.

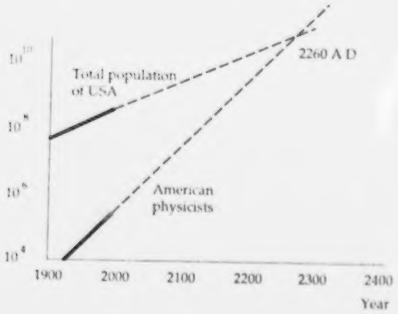

Fig 3: the dangers of extrapolation

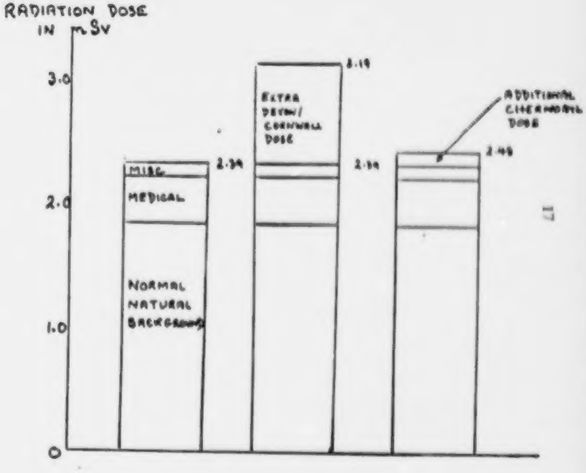

Fig 1.

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Conclusion

I have ranged widely in this opening talk, but I hope I have surveyed some of the issues which will no doubt be covered in detail during the next few days. The topics of this conference are all important ones: teachers need help if they are to bring them effectively into their teaching. I hope this conference will encourage the development of appropriate resources and ideas which can be put to use in education.

Last of all, I have one regret about this talk. Physics education should be fun and a lecture without an experiment is no fun at all. So I will finish with an experiment of mine which I do merely because it is fun in the hope that it will remind you that there must always be fun in teaching physics.

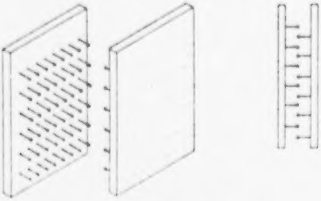
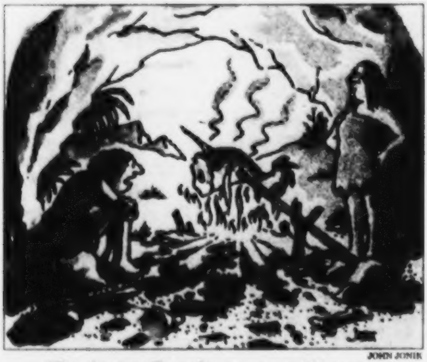


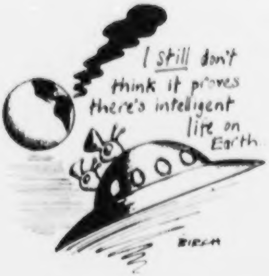
Fig 4

It is not very easy to demonstrate chain reactions in the classroom. I have here two sub-critical masses of 'uranium' (see Fig 4). I light one of the matches at the bottom. It is too far away from the match above to be ignited, but when I bring the two masses together ... we soon get the chain reaction I wanted ... and I can finish my lecture in flames.

ENERGY EDUCATION



"You figure it. Everything we eat is 100 percent natural yet our life expectancy is only 31 years."


I still don't think it proves there's intelligent life on Earth.
BIRCH

ENERGY, CHANGE, DIFFERENCE AND DANGER

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On being alive

On the day I happen to be writing these words, there is a storm blowing over London. The trees are bending in the wind, and it is difficult to walk upright. Circular eddies of wind form in enclosed spaces; indeed the weather map shows just such a large eddy - a depression - covering the country. The impression of an elemental source of change is overwhelming. To go for a walk, or to work outside, I must exert myself: use myself as another elemental source.

Thermodynamically, what is going on? Today's events are events in an *open system* through which there is a *flux of energy* , a flux occurring because of a continual *entropy increase* (or *free energy decrease*), in a system sufficiently far *from equilibrium* to *generate structures spontaneously*. My own body is yet another such system. Even these words come to you by courtesy of non-equilibrium thermodynamics!

When we find out how pupils, or ordinary adults for that matter, think about energy, we find a number of common so-called 'misconceptions'. Energy is often imagined in a vitalistic way, as having to do with being alive. A person's energy has to do with their power to act, and derives from their well-being - food may 'trigger' the making of energy but is not so readily seen as a carrier of energy. Energy is seen as being 'used up' in action, but sources like the Sun (or my body) can provide energy without ending up with less. Energy is seen as having a certain creative power. Language and culture confirm, and may help to induce, these and similar ideas. We have many common words for the same cluster of thoughts: energy, activity, action, power, force, strength. Every single one that I can think of has been recruited by science for a different purpose!

Such a way of thinking is consistent with what Piaget tells us about the early construction of intelligence. Thus those (including me) who find his story compelling think of intelligence itself built by the child out of two ingredients: the child's actions and visible movements. The idea of a cause is modelled on the child's own actions, which are themselves elemental (uncaused) causes. Movement and cause are indissociable: a movement must have a cause. The world has a before and after, which orders causes and effects (so time's arrow is built into our thinking even before time itself is established).

Those who dismiss the Piagetian story may however accept another facet of our human constitution, drawn from neurology. We, like other animals, are built to pay attention to *differences* . We notice movement. We attend to edges between bright and dark. Hot or cold things make us react.

Sameness or featurelessness tends to pass us by. This is hardly surprising if our genes are to survive to further generations in a world both driven by difference and containing differentiated structures.

In summary, we tend to think of energy as the creative power to generate differences. We are not wholly wrong to do so, since there is something which has such a power. But it is not energy, it is difference itself. It takes a difference to make a difference.

On limits to change

As babies, we learn that it is not possible to walk through the walls of the room. Our early conception of space is rather topological - not the infinite empty space of Newton but an affair of inside and outside. Physics recruits the concept very often, notably to make the idea of a *closed system* . A closed system is a conceptual sealed room. Nothing, real or unreal, can get in or out. It is found that in such sealed rooms of the mind, there are limits to what can happen. One of these limits is that the total energy cannot change. That is, if we think of all the variables which describe the state of affairs in the sealed room, their values can only change to other values such that the total energy neither rises nor falls.

A way of thinking about this is to think of being restricted to move on a surface, much as (more or less) we are tied the ground. If variables are like dimensions of a space, the interior of a sealed system cannot walk anywhere in that space, but must move only on the 'surface' defined by the total energy being constant.

Thus from this point of view, the total energy is a *constraint* , not a generator of change. It is even wrong to say, "only those things for which there is enough energy can happen". Events for which the total energy gets less cannot happen either! All that can be done is to *trade energy* from one part of the sealed room to another.

Things can happen in a sealed room only if it contains *difference* . There are two kinds of difference to discuss. One is the kind to do with forces and motion. The other is the kind to do with hot or cold, concentration or diffusion. The first kind concerns movements of particles considered one at a time. The second concerns changes related to patterns of distribution of very many particles. The first is dynamics and the second thermodynamics.

On ceaseless change

The first kind of difference is one we associate with springs. If the total energy would change if the length of the spring changed, and nothing else changed, then something can happen. Of course, just this event *cannot* happen, since it would change the total energy. But if the total energy would also change if the speed of a mass in the sealed room changed (and nothing else changed - again impossible), then the spring can change length and the mass can speed up or slow down. Perhaps you recognise this story as that told by Hamilton's equations.

This (not too remarkable) change can happen only if the variables are *coupled*. The mass has to be fixed to the spring, not just lying around in the room. There must be a possible interaction between spring and mass. So this kind of change runs on *virtual differences of energy coupled together*. The only changes which can occur are those for which there is in the end *no difference* of total energy, but in which some energy is traded. Energy trades select which motion occurs.

Nothing at all will happen in the first kind of sealed room if its contents are *in equilibrium*. 'Being in equilibrium' means that no small changes to any of the variables will alter the total energy. For example, tipping a balance with equal weights on either side does not change the total energy. The tilt is a quantity which does not make a difference. And nothing happens.

Because we human beings pay such attention to motion and actions, we see motion as change and as needing a cause. But the argument above says that the variables of the system just wend their way around phase space on a constant energy surface. If there is no dissipation, the path is closed (or is a point). But ceaseless repetition is not change. A planet orbiting a star for ever, an oscillator going to and fro for ever, are not essentially different from a ball spinning for ever, about which we would say that nothing is changing. Nor do we think of the motion inside an atom as change. Another way of saying all this is that forces such as gravity give directionality, but not directionality in time, which is what we need if we are to have causes.

All this is deeply at odds with a world in which we walk about or drive cars. There there is change and cause of change. They arise just when such a simple system interacts with a system which allows differences of the second kind.

One such case is when oscillating masses, children on swings, or balls dropped in the air come to rest. This looks bad for the idea that the total energy is constant, and was the reason why the idea was so hard to uncover, since it seems so obviously wrong. However, this turns out to be a case of the obvious facts being deeply misleading. The energy is actually *still there*. It got shared out among the molecules of the moving object and whatever it rests on. These molecules really are moving around more and stretching the springs between their molecules more. In the past this was called 'turning mechanical energy into heat'. Now we can see it as trading energy carried by movement and by springs from one big lump of matter to a lot of smaller bits of matter. (Uri Ganiel shows a truck which bounces well off a wall bouncing very badly if it carries a frame containing metal washers on a grid of rubber bands.)

A much trickier case arises from the obvious fact that someone threw the stone in the first place. A person throwing a stone is not a bit like a spring pushing a mass. The first starts an event, while the second just plays its part in the evolution of an event (and may just as well happen backwards in time). Whoever throws the stone seems to be an elemental source of change, a *deus ex machina*, able to interfere in this otherwise mechanical universe. The difficulty is so lethal that it is usually totally ignored. We are now talking about a simple conservative few-particle system acted on by an open system (the person) which is far from equilibrium and is taking advantage of that state to introduce a bit of difference into the simple system. To make that difference we need the creative power of the second kind of change.

On difference

The second kind of change is that which created the storm. Differences in temperature between Sun, Earth and space, producing on the Earth temperature differences between the poles and the equator and between the lower and upper atmosphere, produce the weather.

There are two kinds of change driven by differences, or rather there appear to be. One kind is the cooling of a cup of coffee left alone. It goes all by itself to equilibrium. Difference spontaneously disappears. The storm is the other kind. Here difference is *created* : pressures change and winds blow, in a structured pattern. What has happened is that a larger amount of difference has vanished, creating a smaller amount. It takes a difference to make a difference.

What *is* 'difference', in this sense? It is the presence of pattern or organisation. It is the opposite of sameness or featurelessness. It is the limitation of possibility. Thus it is also related to information: without difference there can be no information.

Difference can be quantified. If there is pattern, then certain possibilities are excluded. The total number of possible arrangements open to a system measures sameness within it. Its reciprocal measures difference. Usually we take the logarithm of the number of possibilities, so that its negative measures difference. That is, difference is measured by negative entropy. To say that entropy increases, or negative entropy decreases, is to say that difference vanishes. Why must difference vanish? It vanishes because systems made of many particles evolve just by the random chaotic movement of the particles. If a possibility opens up, they find it, just by chance.

The storm was a region of the atmosphere containing vigorous differences, but it was transient. The spontaneous vanishing of difference saw to that. But some differences can be trapped or constrained for longer. A vacuum flask stores a difference in temperature for most of a day. A cylinder of compressed gas is kept like it is by the strength of the metal of the cylinder. A gold coin keeps a difference in purity stored for centuries, as does a lump of coal. This kind of preservation of difference is done by *decoupling* , by preventing molecules from interacting. It was important in the evolution of the Universe that radiation became decoupled from matter, so that difference stored in atoms went on existing. This static kind of maintenance of difference is the basis of the concept of a closed system.

There is another way of maintaining differences, which is to create more to replace that which is lost. This is what our bodies do. A simpler example is central heating: we keep the house warmer than the outside by continually refreshing the difference. The Sun does the same for the Earth, keeping it lukewarm compared to the space surrounding it. This can only be done by continually using, and destroying, a bigger difference. To keep something in a steady state, far from equilibrium, requires the continual removal of a bigger difference.

But something in a steady state, far from equilibrium, can also be a source of the difference needed to make other, smaller, differences. The production of the storm from the difference of temperature between poles and equator was one such example. I am such an entity too and can use my state of difference to make differences. So such things are sources of creative power. Because they are in a steady state, kept there by yet other larger still sources of difference, it can appear that creating a difference uses nothing up. Children we have worked with think of people, and the Sun, as being sources of energy but not necessarily as using it up.

'Being used up' more obviously happens to stored or trapped differences. As coal is burnt, and carbon and oxygen once split apart by plants come together again, a difference evidently vanishes while for a time making another in heating a room or a furnace.

On Danger

Zero difference is death, but big differences can be dangerous. Very hot things, as well as burning us, are potentially dangerous because they can make big temperature gradients which in turn set things in motion and make storms or run powerful engines.

Trapped differences can be unexpectedly big and dangerous too. Fire from the trapped difference in coal is liable to be as hot as the Sun's rays, which made it. The trapped difference in the nucleus is associated with a much hotter source: the interior of exploding stars. So if we use up some of this difference we can very easily burn our fingers. To use it is to play with a very hot fire. Its creative power can generate differences, such as those in explosions, which we do not want.

But playing with a very hot fire has a big advantage. The very large difference it provides has great creative power. We can use it to make new differences which we want or to maintain differences we want to keep. Cooler fires have less difference and less power, and because of that have not the potential to create a difference which harms us so much.

We have to choose, since we are steady state systems which have to feed on difference to stay as we are. And we like to build more such systems to live in. So we need difference for the very same reason that it is dangerous.

On teaching

How can we think about teaching about energy and change, so that these ideas emerge? How can we make best use of and develop the ways children spontaneously think about such things?

In the primary school we ought to pay a lot of attention to difference and to the vanishing of difference. Examples can include paints in water, blown up balloons going down, and warm things cooling or cold things warming. Three principles can be stated and [illegible]

differences tend to disappear
differences make changes
it takes a difference to make or keep a difference

Quite a lot of attention can be given to the importance of hot and cold. A burning glass shows that the Sun's rays are as hot as the Sun. A walk on a dark winter evening shows how cold is the space filled by stars. Films of distant regions can bring out how hot it is in the tropics and how cold at the poles. Studies of the weather, with weather maps and satellite pictures may give a feeling of a turbulent atmosphere stirred up by these differences.

Studies of diet can emphasise how food keeps us going. Starting with dying plants, we can explain how life stopping involves the organic matter no longer being kept different from its surroundings. While it keeps enough difference, other organisms can use it as food.

Primary teachers should know that here they are making an important contribution to learning ultimately about the direction of change and the sustenance of life.

We should also pay attention to what limits change. Toy cars run on curved tracks do not run up higher on one side than on the other. A bouncing ball does not rise higher than it was dropped. A flame burning for a time makes a lot of water less hot than a little water. A small heater, even if red hot, does not warm a large room enough.

In the secondary school, we must at some point confront head on the fact that we need to think of energy stored in space (fields). That is to say, if we have a mass and a spring, the spring helps the teacher by being a visible object; something real with which to associate part of the energy. To deal with a stone thrown in the air, one needs to imagine a 'gravity spring', with energy stored in the field around the Earth and the stone. (The gravity spring pulls the same, or less, as it is stretched). Playing with magnets may make the idea that 'empty space' can store energy seem less unbelievable. If pupils ask whether anything (energy) is 'really there', one should answer "Yes, it is" . One can add that it is real enough to attract things by its own gravity, just as do stones and the Earth - the most 'real' things that there are. And of course light and radio waves are another case of energy in space, which happen to be travelling.

So simple mechanical systems would be talked about as cases of energy being traded between movement and field. Gravity gives a direction so that we have 'up' and 'down', which means that when a stone is going up the trade is in one sense and is in the other when it comes down. The energy trade does not *cause* the motion: it just selects out which motion will happen by keeping the total energy constant.

Just what to call 'difference' (that is, negative entropy) is a puzzle. Exergy (or as Gibbs called it, essergy) is a near relative in scientific terminology, but not one well known to many teachers. I believe it to be essential to get as soon as possible to an account in terms of molecules. Otherwise, how can we say anything about the spontaneous decrease of difference?

Perhaps the essential point is to reach a classification of kinds of change, so that one kind of problem can be distinguished from another. We might try:

1 Equilibrium: where there is no difference, no change and which lasts forever if undisturbed.

2 Dying difference: where a difference, often small and near equilibrium, spontaneously dies out and reaches equilibrium. No other differences need be produced.

3 Productive dying differences: where a difference, in vanishing, produces other differences on the way. A storm blowing down a tree is an example, as is a fire, or an engine.

4 Trapped difference: where a difference, created by other larger differences in the past, is kept as it is and has no coupling via which to decay. Fuel is trapped difference.

5 Continuing differences: where a difference is kept in being by the continual vanishing of difference from some other source.

Here is the source of change: driven by difference and limited by energy.

Nothing ventured nothing gained.

old English proverb

SAVING ENERGY AS A NEW RESOURCE

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> Die erste Eigenschaft aller Ursachen nennen wir
> ihre *Unzerstörlichkeit*
> Die Fähigkeit, verschiedene Formen annehmen zu können,
> ist die zweite wesentliche Eigenschaft aller Ursachen
> Beide Eigenschaften zusammengesetzt sagen wir
> Ursachen sind (quantitativ) *unzerstörliche* und (qualitativ)
> *wandelbare* Objekte
>
> (Robert Mayer 1842)

Introduction

The energy consumption of the world has reached a measure that the positive effects of making life easier for mankind are more and more superimposed by negative secondary effects on our surroundings which are going to develop into main effects. Therefore, saving energy is one of the most important goals which has to be achieved in the future.

One important measure to save energy is of course to reduce the energy consumption by restricting the energy consuming demands of mankind.

But at the same time, there are further possibilities not yet exploited: One *huge source of energy available* in industrial countries is *the energy we currently waste*. In this connection, we only mention the differences in consumption per capita of countries at comparable standards of living. For instance, West German people need only somewhat more than 50 percent of the consumption of people in the United States, and even West Germany is far from using energy in a very efficient way.

The question is, how can this large, clean, cheap, and save source of energy be made available. This question aimes at a drastic change of the existing *patterns of energy consumption* which stem from a time where the restriction of energy resources and the environmental risks have not been recognized. However, to our opinion, the capability of changing the human habits of energy use relies mainly on an appropriate understanding of energy: The consumer has, above all, to learn that energy exists in different qualities, and how this quality can be matched with the quality of the job desired. In order to achieve this goal, a lot educational work has to be done.

The conceptual background

Here, we shall only investigate this problem as far as physics education is concerned. Therefore, our problem is to show how the learner can be made familiar with the conceptual background of energy and energy waste which is a necessary pre-requisite of an effective energy use. Although this implies the development of a clear physical characterization of energy consumption, we tried to keep the level as low as possible in order to reach the untrained student, too. One important step towards this objective has been to start with the students' everyday life understanding of energy.

The details of this procedure have been reported elsewhere [1,2,3]. We shall only repeat the mains results:

According to our investigations the approach to the energy concept is commenly obstructed by learning difficulties relying mainly on two factors:

Firstly, energy is usually derived *from mechanical quantities* according to the scheme:

force → work → energy.

This implies that the understanding of energy is intended to follow from an understanding of a combination of quantities which are, already themselves, very difficult concepts. Therefore, we plead for a direct introduction of energy based on simple phenomena of the everyday life world making use of the common sense representation of energy.

Secondly, and this point is closely related to the first, the (physical) introduction of energy is restricted to experiences which rely on *energy conservation*. However, the common sense understanding of energy is determined by experiences which reveal additional aspects of energy. The most important ones are to our opinion the aspect of *energy consumption* and the aspect of *drive*.

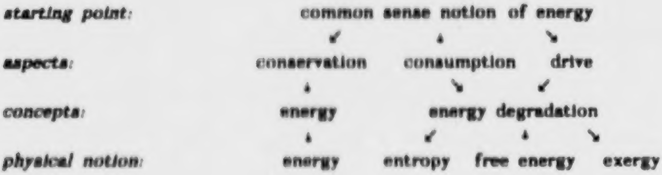
The aspect of consumption is e.g. expressed by the appeal to save energy, by the fact that one has to pay for energy, and by the possibility that energy ressources may be depleted.

The aspect of drive may be encountered within the students' representations as a kind of universal fuel in situations where energy provides for the drive of processes.*(Energy keeps the world go around!)*

In order to avoid serious learning difficulties (How can there be a depletion of energy resources when energy is conserved ? Or, how can a car be driven by energy if the cars energy is conserved, thus, stays unchanged?) the conceptualisation of *conservation* alone turns out to be unsufficient. Therefore, we propose to conceptualize *consumption* and *drive* as well: Starting from the *common sense use of the word energy*, elaborating the *aspects of conservation, consumption, and drive* we finally introduce the physical concept of energy covering conservation, and the concept of *energy degradation* conceptualizing both the experiences of *consumption and drive*.

After all, this is not different from what has been done in physics. Already Robert **Mayer** who did the first steps toward the physical quantity of energy felt that the aspect of *indestructibility* was only half of the truth and had to be complemented by the *changeableness* (see our motto above). The ultimate physical conceptualisation of this additional aspect was later undertaken by Rudolf **Clausius** by introducing the quantity of entropy. However, as entropy has always been regarded as too difficult for educational purposes it simply has been disregarded bringing about the difficulties just mentioned.

The concept of energy degradation proposed here is a prelimenary concept which may provide for a qualitative understanding of most of the energy problems in question which, if necessary, may be quantified in a simple and direct manner to the physical notion of entropy [3].



Energy degradation

In order to conceptualize what is understood by energy in everyday life, we start from the observation that the aspects of conservation and consumption do not necessary contradict eachother. On the contrary, according to our findings, they turn out to represent *complementary aspects of the same thing*. This is not only true for energy but also for other substancelike quantities where, as a matter of habituation, such an apparent contradiction is not noticed at all. For example, when we talk about consuming or using up water we do not assume that water is annihilated while it is used for washing, cleaning or flushing the water closet etc. If you ask students what is happening to the water when it is used up they will answer in their own words that it is *conserved in quantity* but *changed in quality* in that it cannot be used again for the same or even for a more ambitious purpose. This conviction manifests itself in the fee charged for the disposal of spoiled (waste) water, and it is common practice to calculate its quantity from the freshwater delivered to the household. Other examples are, e.g. the consumption of food, of building materials etc.

As typical energetic processes we mention e.g. the burning down of a candle, and the cooling down of a pot of hot tea to the temperature of the (cold) surroundings. In both cases the energy is not annihilated but drawn to the surroundings from where it does, however, not return itself reconstituting the original state (see fig. 1a and b).

This kind of processes has formed our intuition to regard consumption and conservation as compatible principles.

Another important point is that the consideration has switched to the *process* character of the corresponding activities exhibiting a pronounced asymmetrie in their flow. Therefore, based on this well established intuition we may conclude:

Each spontaneous process is associated with an energy degradation, which is due to the fact that it does not run down spontaneously in the opposite direction.

This principle of degradation may be regarded as a preliminary qualitative equivalent of the *entropy principle*.

However, we also can observe processes run in the opposite direction. That this observation does not contradict the principle of degradation can be illustrated by putting a candle under a pot of cold tea (fig. 1c) and letting it heat the tea again. Although the process of burning stays the same as before, the process of cooling is forced to run in the opposite direction. As the spontaneous process of cooling goes along with energy degradation its reversal can be considered as an *energy upgrading process*.

Discussing further examples from different areas of application we easily may arrive at the generalized statement:

Each spontaneous process (considered as already run down) may be reversed by another spontaneous process. Thus upgrading energy may always be realized by degrading energy, or even more simply: *Energy downgrading drives energy upgrading*.

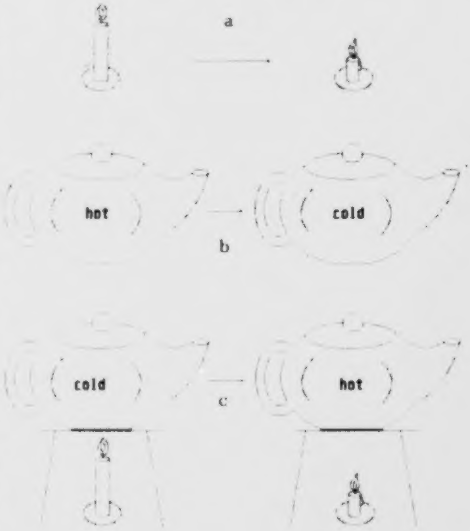


Fig. 1: Example of spontaneous processes. The process a develops a greater devaluation because it can drive the process b backwards.

This simple formula will be central for choosing energy saving paths to accomplish a certain work. But before discussing this, we have to answer the question often raised at this place whether this upgrading does not signify a violation of the degradation principle, thus being in disaccord with the second law. There is, of course, no violation because the second law makes a statement about all the systems involved in a certain activity. Therefore, our degradation principle applies to the total process which in our example is the combination of the spontaneous process of burning and the driven process of heating.

In order that this total process actually takes place it must leave a net energy degradation which implies that the upgraded energy has to be smaller than the degraded energy associated with the driving process. Because of this "subtraction" of the upgrading from the degrading a spontaneous process driving another process (backwards) leaves a smaller degradation as if it would run down alone. In our above example, this fact does very well fit to our feeling that the mere burning down of a candle is a waste of energy while when, at the same time, tea is heated something usefull is done.

Moreover, the above statement expresses also the driving aspect of energy degradation: *Therefore, energy degradation is not a negative diabolic principle, as often stated in connection with the characterization of entropy. On the*

contrary, it has to be considered as the necessary condition of the possibility that something may happen.

Within the scope of this conception ***the consumption or use of energy may be regarded as a controlled application of "available" processes to reverse other processes in order to let them again run down to deliver heat, motion, sound, light or what kind of effect actually is needed to satisfy the various human wishes and requirements.*** Energy waste turns out to be present each time a spontaneous process runs down without (or only incompletely) driving another useful process.

Haste makes waste

The maximal efficiency or zero waste of energy would be achieved by approaching the ideal condition that the upgrading effected by the driven process totally compensates the degradation of the driving process. However practically, this is impossible because zero degradation means no activity at all. In order that the total process can actually run down, there must at least be a small degradation. In a certain sense, the amount of net degradation is a *measure of the "speed" of the process*. For instance, if hydrogen gas is simply exploding, i.e. effecting nothing else in the world, the speed of the process i.e. the rate at which chemical energy is transferred to the surroundings, and the devaluation effected by it are maximal. But even if it is burned in a controlled way in order to produce a certain temperature difference, the corresponding upgrading is rather poor. The well known waste of energy in power plants is due to this rather violent procedure. A significant decelleration of this process, and therefore a drastic reduction of the net degradation can be achieved by harnessing it, e.g. in a fuel cell, to keep an electric current flow. However, this kind of direct conversion of chemical energy is so slow that the rate at which the electrical energy is produced is too low to be interesting for our high level energy demands. For essentially the same reason, our cars are driven by energy wasting explosion motors and not by more efficient but not so quick Stirling motors. Finally, the disappearence of wind, water, animal, and human powered drives must be considered as a direct consequence of the haste of the modern world. But as we could show: *Haste makes waste*.

Heating a room

Regarded from the work desired the "driving" process is relatively unspecific. But from an energy saving point of view the kind of the driving process is important.

For example, a room may as well be heated by means of an electric radiator dissipating electrical energy as by means of, say, an oil heating. In both cases, the effect within the room is the same but the overall effect, i.e. including the change left in the surroundings is totally different. Although, electrical energy is known to be totally convertible into heat, this method of heating is one of the most energy wasting: For, related to a certain amount of energy, the dissipation is just used to upgrade the corresponding thermal energy (respectively, reversing the process of cooling just once). However, it could have been used to upgrade a multiple of the thermal energy (respectively, reversing the cooling down several times). Practically, this may be realized by using a heat pump which upgrades additional (thermal) energy of the surroundings and draws it to the room. The degradation of the electrical energy driving the pump then accounts for upgrading thermal energy of the surroundings. Proceeding in this way, about three times as much energy may be upgraded as if the room was heated by an electric radiator. The efficiency is thus raised by factor of three.

However, closer inspection shows that this efficiency increase just compensates the energy wasted in a power plant by producing electrical energy which is roughly realized by the reverse process. Thus, in this case the heat pump is not better than an oil heating if one disregards the fact that the power plants often are driven by materials which cannot be used in a household (as e.g. low quality coal; and uranium). But the detour via the power plant and the corresponding waste of energy could be avoided by using e.g. a Diesel engine.

Another point of energy waste may be detected within this example: The energy saving measure to operate a radiator at the lowest temperature feasable depends essentially on the density of the energy flow transferred to the room. This density may be kept at a low level if

- the surface of the radiator is great and/or
- the energy flow to the surroundings is small. Therefore, using radiators with a great surface, as e.g. the floor or the walls is not only a question of room design and thermal comfort but also of energy saving. The same is true for reducing the flow of energy to the surroundings which may e.g. be realized by optimally isolating the walls.

By means of this special example of energy use we wanted to demonstrate in the spirit of our devaluation concept how the studends' attention may be drawn to specific sources of energy waste which are likely to be overlooked within a merely energy i.e. conservation oriented kind of consideration. Of course, the detection of energy waste may not automatically be changed into energy saving measures. But it must at least be regarded as a necessary condition to discuss and design alterative techniques which finally could induce a change of the above mentioned pattern.

Quality of energy

In order to account for the several aspects of the everyday life concept of energy, sometimes, different values or qualities are assigned to the different energy forms [4] (see also the motto of Robert Mayer) according to the following scheme:

high grade: mechanical energy ↔ electrical energy
↘ ↙
(chemical energy)
↓
heat (T_1)
↓
low grade: heat ($T_2 < T_1$)

(For the sake of simplicity, we only considered temperatures above the temperature of the surroundings T_s. For temperatures T below T_s the value of heat increases with decreasing T)

This hierarchy of energy forms can direc[illegible] founded on the concept of degradation (for details see: [1]) by *qualifying an amount of energy of a certain form as more valuable or of a higher grade as the same amount of energy of another form if the degradation combined with its dissipation is greater; or in other words, if the first dissipation process may drive the latter (backwards).*

As each heat conduction process regardless of the temperatures involved may, in principle, be reversed by the dissipation of (an equal amount of) mechanical (or equivalently: electrical) energy this form turns out to be the most valuable.

Unusual driving processes

In the following, we shall show some features of our conception going beyond the conventional discussion of energy saving measures. The fundamental statement that each spontaneous process may be harnessed to reverse some other process usefull for us in one way or the other may draw our attention to driving processes which at first sight seem to have nothing to do with energy, and therefore are overlooked at all.

For example, a spontaneous process par exellence is the mixing of, say, salt in water. How can it be used, conventionally spoken, to generate energy? It is well known that by separating pure water from a salt solution by means of a semipermeable membran the disorder producing mixing process (corresponding to our devaluation) may raise the level of the solution, thus reversing the process of falling, respectively, producing potential energy. In this connection, it is interesting to note that the (relatively) pure water of the rivers flowing into the salty ocean represents a (theoretical) potential of usefull energy corresponding to a water fall of about 200 m. There are only economic reasons for not realizing this idea [5].

Another example is a possible utilisation of the spontaneous process of evaporation which again could be harnessed to lift matter and produce potential energy. There exists a beautifull model of this unusual power plant in form of a toy called dunking duck [1].

In order to get a survey of possible driving processes we elaborated the following scheme:

In a horizontal line we listed usefull (driven) processes, and in a vertical column we set against the corresponding spontaneous (driving) processes, thus representing a kind of matrix. The problem was to find for each combination of driving and driven process a possible and direct realization. (We did not succeed in each case) The interesting point was that some examples turned out to be rather unusual, thus making aquainted with new physical or chemical processes and alternative realizations of wellknown processes.

This matrix exhibits a multitude of possible driving processes offering the possibility of an optimal matching with the work desired.

As a general conclusion, again a change of the present pattern of energy consumption is suggested here: Instead of centralizing our energy system, basing it more and more on our geological energy capital it should be decentralized and based on the better adapted, renewable, and save natural income.

driven process / **driving process**	**production of a temperature difference**	**production of a pressure difference**	**production of mechanical energy**	**production of an electrical current**	**production of a chemical fuel**	**ordering**	**condensation**	**emission of light**
temperature balance	heating an object in a heat bath	making jam	power plant convection	thermo generator	decomposit of water	cristallisation	cloud, fog	glowing of matter
pressure balance	freezing by gas expansion	inflating a ball by pressed air	wind	piezoelectric effect		freezing of expanding gas		
(mechanical) dissipation	heating of car brake	inflating a ball by a pump	water wheel lever	electrical generator		sedimen-tation		glowing borer
(electrical) dissipation	electrical heating	reverse of piezoelectric effect	electromotor	electrical induction	electrolysis			electric bulb
burning of a (chemical) fuel	cooking water	heating of an enclosed gas	muscle	fuel cell	synthesis of a chemical compound			candlelight
mixing, solvation	H_2SO_4 in water	osmotic pressure	lifting of a fluid by osmosis	galvanic element		precipitate reaction		
evaporation	eau de cologne on hand	rapid elevation of vapor	dunking duck	production of clouds		production of salt from sea water		
absorbtion of light	solar collector	closed black exposed to sun	Crookes light mill	solar cell	fotosynthesis			fluorescence

Nature as a standard

An optimal matching between driven and driving process reducing net degradation at a minimum is realized in the complex web of natural processes driven directly or indirectly by the overall process of solar light radiated to the earth at a high temperature and reemittet at the temperature of the surroundings (fig. 2). One important example is the decay of biomatter characterized by the formula:

$$[CH_2O]_x + x\,O_2 \rightarrow x\,H_2O + x\,CO_2 + \text{energy}.$$

This process is permanently reversed by the degradation of solar energy *(foto synthesis)* representing an upgrading of dead matter to living systems. (By the

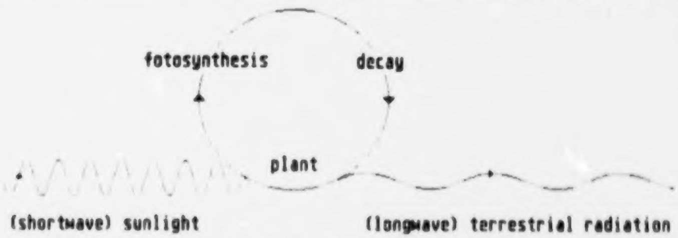


Fig. 2: Schematic representation of a "solar driven" biological cyclic process

way, here we have an example showing that the degradation concept is not restricted to processes where the energetic aspect is dominant but applies as well to processes which are more adequately characterized by an order concept

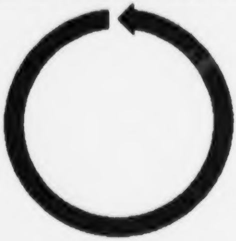


Fig. 2: Natural "circle"

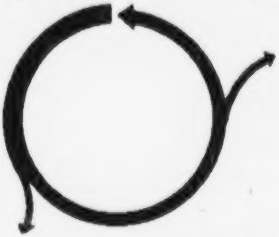


Fig. 3: Natural "circle" disturbed by human activity

accounting for the organization and desorganization of matter.)

The decay process together with its reversal, the production process, may be called a *cyclic process*. Such cyclic processes are typical for nature. They realize in an almost ideal way the avoidance of a net degradation, i.e. a deposal of garbage in the surroundings. Symbolizing this kind of operation by a circle (fig. 3) the economic processes of the human society should be symbolized by a broken circle (fig. 4) or a line *("Die Linie ist das verrottete Fundament unserer zum Untergang geweihten Zivilisation" (Hundertwasser))*

Therefore, recycling processes (bending lines back to a circle) represent, à la longue, the sole measure to reduce degradations of matter which represent in many cases degradations of energy, too. The objection to recycling on grounds that it is more expensive than the garbage producing alternatives is based on the illusion that the resources are practically infinite which are essentially the same arguments advanced against the use of solar energy.

Summary

Our intention was to illustrate the statement that the energy we currently waste is one of the largest source available. Unfortunately, the places where energy is wasted use to be hidden behind well established habits and inadequate quantities characterizing the energetic activities. Therefore, we proposed the concept of energy degradation accounting for the important experiences of consumption and drive which are not only ignored by the conservational aspect of energy but even obstructed as investigations with students showed us. Tapping the reservoir of wasted energy aimes within our conception at the minimization of the overall or net degradation associated with a certain activity. Moreover, and even more important, the minimization of the degradation implies in addition a minimization of environmental damage which in the case of the degradation of matter means a minimization of garbage deposal in the surroundings. This kind of consideration emphasizes the process character of (not only energetic) activities simplifying the detection of net degradations and facilitating the search for alternatives. In order to do so, we proposed to elaborate a survey about possible processes. Finally, the fabric of nature could be characterized on the basis of our conception as a complex web of circle processes. Apart from a process oriented understanding of what is happen in nature the method of recycling was recognized as an effective trick to cope with garbage problems.

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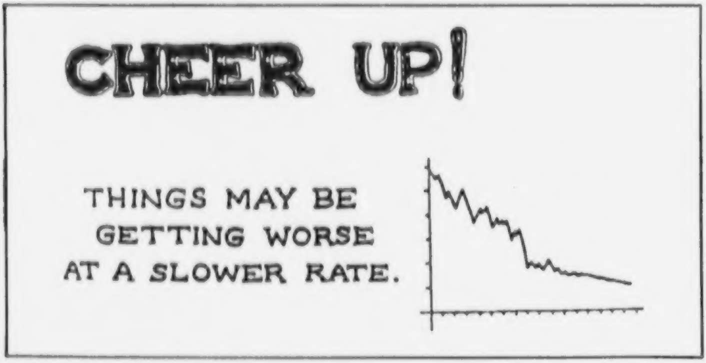
CHEER UP!
THINGS MAY BE GETTING WORSE AT A SLOWER RATE.

TEACHING ABOUT EFFICIENT USE OF ENERGY

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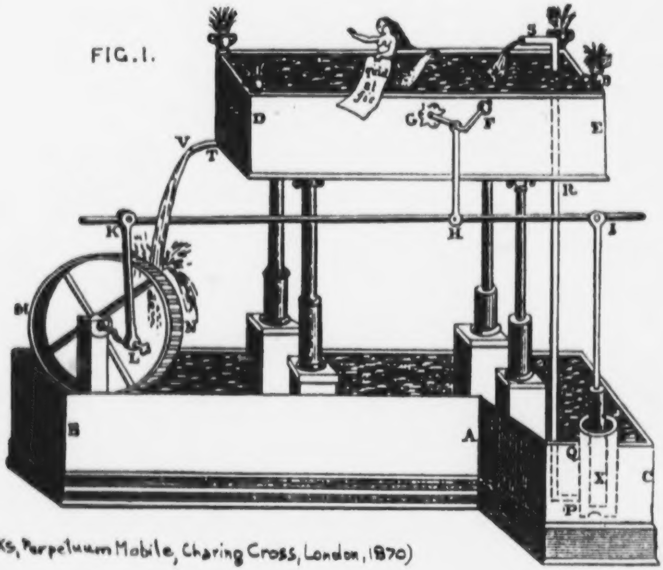
The device in the picture (fig 1) looks like a very nice, efficient device with little demand in terms of energy and of impact on the environment.

FIG.1.



(H. Dircks, Perpetuum Mobile, Charing Cross, London, 1870)

Having the water in the lower reservoir, it is necessary to pump it up to the top only once. When the water flows downhill, it is losing gravitational potential energy, which becomes available for turning the turbine. The energy stored in the turbine is then used to raise the water again to the top, ready for the next descent. Extend this principle to other system and it is clear that the problem of diminishing energy resources would disappear. Why not put a similar device as a leisure facility in the Balaton lake?

In fact, nobody would believe in this device for it is a perpetual motion machine. The principle that a perpetual motion machine is impossible was already widely accepted early in the eighteenth century.

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According to the laws of energy, we cannot get anything for nothing; and, moreover that, we cannot even break even. So, we have to put petrol in our car to make it run; and, what ever energy we use to start it, a side effect of running the car will be an heating of the surroundings.

The problem arises then of how to improve the performance of possible devices in order to save energy and to affect as little as possible the quality of the evironment. Such a study of efficiency in the use of energy is an issue of concern to society worthy (1) to be included in a Physics Course at Secondary level. In this brief essay, I would like to consider some tools of analysis we can offer our students in order to deal with such issue.

Representing the energy flow

A first tool of analysis are the so called "Sankey-diagrams", which exhibit the transformation of all energy inputs into a definite combination of "useful" and "rejected" energy.
Common examples for some 'ideal' and real devices are given in figs. 2-3-4-5.

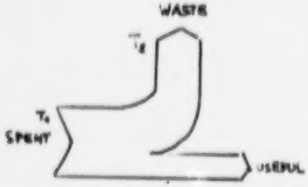

FIG. 2 IDEAL THERMAL ENGINE

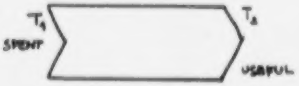

FIG 3 IDEAL FURNACE

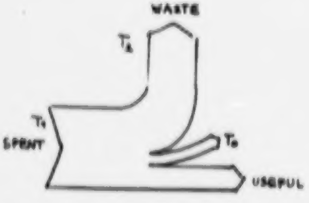

FIG. 4 REAL THERMAL ENGINE

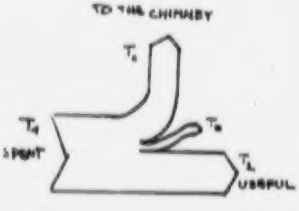

FIG 5 REAL FURNACE OR BOILER

The diagrams claim for the conventional efficiency n (defined as the ratio of the amount of useful energy to the amount of energy spent to run the device) a value η=30% for a real thermal engine (it could be a car engine or also a power plant); η=75% for a real heating system. This would lead to conlude that 75% efficient water heating and space heating could scarcely be improved, while 30% efficient electricity production is ready for a major breakthrough.

As a matter of fact, this conclusion is not wholly true. The reason is to be found in the fact that in general energy accountings systematically ignore reference to the quality of energy. In fact, these diagrams point away from the distinction that does exist between thermal and non-thermal energy.

As we know, the laws of energy do not allow thermal energy to be completely transformed into other forms of energy. In contrast, other forms of energy in principle can be completely trasformed from one form into another. All the non-thermal energies, then, are uniformly of "high quality", while the quality of thermal energy depends on its temperature. The thermal energy at the temperature of a flame is of rather high quality; it is almost as high a quality as nonthermal energy. However, thermal energy at the ambient temperature, i.e. the temperature of the out-doors, is of zero quality.

Availability

The quality of energy is given by its availability for work production.

If we do 10000 J of work in pumping 100 l of water to the upper reservoir, the water can do very nearly 10000 J of work while coming down and returning to its original state. However, if the potential energy is not stored, it will found as thermal energy of the water in the lower reservoir: the result of the fall being a rise in temperature of the water. This is easily found to be about 0,024 K, and, in returning to its original condition—say, room temperature—it might, theoretically, be made to do some work, but it must also get off some heat at lower temperature. The maximum fraction of input energy that can be turned into work is the ratio of the drop in temperature to the final temperature, or 8·10°K. Therefore, instead of the 10000 J available to do work we have only 8 J when it is thermal energy.

The physical quantity associated with availability of energy for work production is the maximum available work B or exergy. In a previous work (2) exergy has been defined according to the APS study on Efficient use of energy (3) as follows:

Exergy of a body or a system is the maximum work that can be provided by a system as it proceeds to its final state in thermodynamic equilibrium with the atmosphere.(by atmosphere we mean an appropriately large reservoir comprising the environment of the system; usually it is in fact the

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atmosphere)

As we have pointed out in the water reservoir example, while energy is conserved, the availability to do work or exergy is not: an energy output at ambient temperature corresponds to a destruction of exergy. This is shown in the diagrams of fig 6-7 where an exergy analysis (4) is added to the energy analysis.

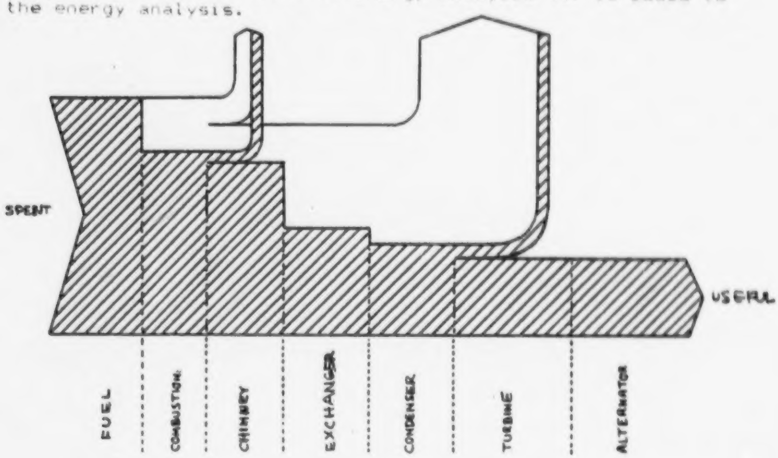
SPENT
USEFUL
FUEL
COMBUSTION
CHIMNEY
EXCHANGER
CONDENSER
TURBINE
ALTERNATOR

FIG. 6 ENERGY AND EXERGY FLUX IN A POWER PLANT

☐ ENERGY
▨ EXERGY

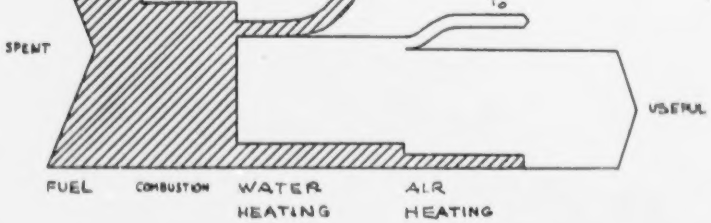
CHIMNEY
T_1
T_0
SPENT
USEFUL
FUEL
COMBUSTION
WATER HEATING
AIR HEATING

FIG 7 ENERGY AND EXERGY FLUX IN A CENTRAL HEATING SYSTEM

If we now define a second order efficiency ε (2) as the ratio of the amount of useful exergy to the amount of exergy spent to run the device, we get ε = 5% for a heating system; ε = 30% for a power plant.

These results show that heat s done least well and electricity generation is done best. In fact, a heat pump is four or more times more effective than common furnaces or boilers at using fuel or electricity to heat air or water.

Joint production

As a matter of fact, also efficiency in electricity production can be improved. The joint production of marketable heat and electricity is one way to do better.

Most electricity is now generated at central power plants by burning fuel to produce steam which drives a turbine. As we said, in the process about 30% of the fuel energy is delivered as electricity to users; most of the rest becomes warmth that is carried away from the generator by water.

Scientists and engineers have been trying to find ways to use the warm material that is a by-product of electricity production. Other scientists and engineers have tried to turn the process around to produce electricity as a by-product of heating.

As a results of these studies, various total energy systems have been developed. An exemple is the Totem, made by Fiat in Italy. This modular integrated utility system can be used in factories, schools, apartment buildings, etc. The idea is that, since these places burn fuel energy for heating purposes anyway, a small extra amount of fuel could be used to produce electricity very efficiently.

An energy /exergy analysis of TOTEM is given in fig 8.

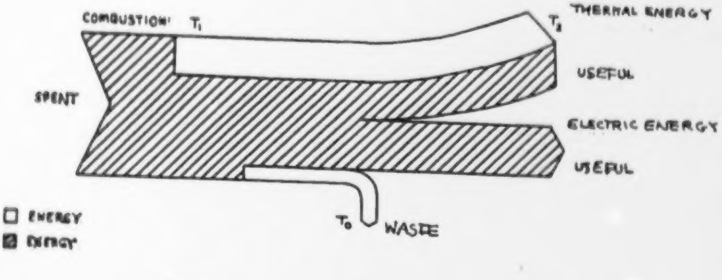

FIG. 8 ENERGY AND EXERGY FLUX IN A TOTEM

The device has a conventional efficiency η=27% as electric generator, while η=91% in the joint production of electricity and heat. The second law efficiency is [illegible]=27% for pure electricity and could reach [illegible]=63% for joint production.

Conclusion

It is a matter of some concern that, in an age in which the great importance of 'energy saving' is increasingly being appreciated, Physics textbooks are still appearing where the concepts of availability and second order efficiency are found not to merit any mention. The examples outlined above are then meant to give some suggestions about how to integrate the teaching of efficient energy use in a Physics course at Secondary school level.

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A RESEARCH BASED STRATEGY FOR TEACHING ABOUT ENERGY

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1 Introduction

Usually in physics education the energy concept is introduced in its fundamental scientific meaning, from which conservation is a central feature. Initially it is taught in some elementary form.

Research findings show this energy concept to be very difficult for most students, mainly so because they appear to hold alternative frameworks on energy, which have strong roots in every day language and experience. These frameworks are not simply replaced by the physical energy concept during instruction, but remain present in a more or less adapted form, giving rise to conceptual learning problems. As a step towards a solution for the resulting teaching problems, a number of science educators advocate a gradual development of students' energy concepts from daily life meanings to more scientific meanings. This view is for example found in the proposals for new National Science Curricula in the Netherlands (Hooymayers 1989) and Britain (DES 1989).

However, others point to essential differences between common sense knowledge and scientific knowledge (Redeker 1985, Lijnse 1986). If these two are understood as the start and finish of a longer term teaching/learning proces, the problem remains how the transition can be made as continuous as possible.

One way to avoid large discontinuities is to change the educational goals. In other words: not to aim from the start at the scientific energy concept. For example the PLON (Dutch Physics Curriculum Development Project) curricula for lower and medium abilities (Lijnse 1982) aim at a 'practical energy concept', which is comparable to what the CLIS Project (1987) calls a 'citizens' meaning' of energy. This meaning is not vague and ambiguous like every day meanings of energy. Neither does it have the abstract, formal relations of the scientific concept. 'It is none the less quantitative and enables students to consider issues such as transferring energy effectively and getting value for what they pay.' (CLIS 1987).

It is generally agreed, however, that at the level of pre-university education the goal should be the acquisition of the scientific energy concept. In the energy part of the PLON pre-university curriculum (Dekker and van der Valk 1986) the development of the energy concept has been planned in a two step proces. First an extended 'citizens' concept of energy is taught in a 'practice-oriented' unit ('Energy'), that deals with energy consumption and future energy supplies. Secondly, the step towards a scientific energy concept is made in a subsequent 'discipline-oriented' unit ('Work and Energy', PLON 1985). Both units are written for students age 16-17.

By aiming successively at both a more practical and a more scientific energy concept, this curriculum offers an opportunity to do research into the possibilities of a more gradual development of an energy concept.

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This paper offers a preliminary report on this subject, in which some conceptual problems that appeared during instruction will be described as well as consequences for revision of the curriculum.

2 The use of pre-scientific energy conceptions

From research (Solomon 1983, Brook and Driver 1984, Duit 1984) it is well known that students use many pre-scientific ideas, originating from every day meanings of energy, in science lessons. Watts (1983) has described some of them in seven more or less 'intuitive frameworks'. In our research we have investigated the influence of these frameworks on students. Our assumption was that attainment of a good quality scientific concept should go along with a decrease of the influence of intuitive frameworks.
Therefore we given a questionnaire on energy descriptions of various situations, according to a multiple-choice format with open motivations. The questionnaire was administered before and after instruction with the unit 'Energy' and also after instruction with the unit 'Work and Energy'. The results of this investigation showed that pre-scientific energy conceptions were widely used before instruction. We did not succeed completely in categorizing the motivations after Watts' frameworks, meeting similar problems to those reported by Bliss and Ogborn (1985). After instruction with the 'Energy' unit, the use of pre-scientific conceptions had decreased only little, though some changes were statistically significant. After instruction with the 'Work and Energy' unit, though the students appeared to use many scientific terms in their motivations, the use of pre-scientific conceptions had still not changed much. These results were rather disappointing. The teachers and ourselves had expected a much more significant progress in the students' use of the energy concept taught.
We therefore concluded that, although the students had learnt quite a lot, their concept development had not followed the path set out by the curriculum. A reason for us to try to trace and describe the actual development in greater detail.

3 Analysis of student discussions

In addition to the questionnaire we made audiotape recordings of classroom discussions. As learning tasks were often performed in small groups, we were able to audiotape discussions of two particular groups and thus collect a lot of information on the conceptual development of the group members. An analysis of the transcriptions enabled us to detect several 'interpreting frameworks', that students constructed to make sense of scientific terms and expressions offered to them by the teacher and the textbook. These 'interpreting frameworks' are to be distinguished from Watts' 'intuitive frameworks'. The latter describe more or less some basic ideas about what energy 'is', as obtained from interviews. The former pretend to describe some basic interpretations that students construct while struggling with taught subject matter knowledge in a learning process. Of course, a strong influence is present from the one on the other. The 'interpreting frameworks', however, include both every day meanings of energy as well as aspects of the scientific energy concept originating from instruction.
Students appeared to construct and use several 'interpreting frameworks', each linked with specific contexts. For our students an important distinction seems to be the difference between 'technical contexts' and 'natural contexts'. 'Technical contexts' concern technical appliances used to make life comfortable. They are readily associated with energy, though possibly in a pre-scientific meaning. In natural contexts, 'forced' and

'self-evident' processes are to be distinguished. A forced process needs energy to take place, while a self-evident process does not, it occurs by 'itself'. (They may be coupled: throwing followed by falling, heating followed by cooling down). Of course, also mixed contexts exist. The interpreting frameworks found for both kinds of contexts differ in many respects.
It may be that a third kind of context and process should be distinguished as well, concerning actions of living beings and 'animacy', as Bliss and Ogborn (1985) call it. This kind of context, however, did not play a role in the curriculum under concern. For reasons of length, we shall confine ourselves in the following mainly to technical contexts.

4 Some interpreting frameworks

In this section we will describe a number of interpreting frameworks that students used during the lessons with the 'Energy' unit. Unfortunately, in this paper we cannot describe sufficient empirical evidence on which our ideas are based (see van der Valk e.a. 1989).

energy is fuel

The basic idea of this framework says that the 'something', the causal agent, that is used up in technical processes, is energy, which is identified with fuels like natural gas, oil and with electricity. Thus energy is some general fuel. Heat, light and movement have to do with energy because energy is needed for heating, lighting, moving, although they themselves are not energy.
This interpreting framework seems to function, for example, when students discuss about:

- 'containing energy'. The textbook states: 'a battery contains energy'. This is interpreted as: the chemical substance in the battery is the energy contained
- 'conservation'. Students say: 'melted wax has the same amount of energy as solid wax because energy is always conserved' (no wax has disappeared). Furtheron, when talking about transformations, students say: 'chemical energy is transformed into heat energy', pointing to the solid wax and the melted wax.

generation, transportation, consumption

This interpreting framework says basically: energy is generated from (is made by) a source, is transported to the appliance, where it is consumed or 'used up'. It 'exists' thus only for a while. In electrical appliances, students easily distinguish in some way between the source of the electricity and the electric energy. From this, a more general 'interpreting framework' arose when students had to make sense of fuels as energy sources. With the help of this framework students interpret heat, light and movement as forms of energy, generated by a source.
Some remnants of the energy-is-fuel framework may remain, for example, when some students say: 'fuel is energy as it can give energy'.
However fruitful this framework is for making a step towards 'energy forms', it gives rise to many problems. Some examples:

- chemical energy: 'the energy generated from a chemical source'. In this sense there is no distinction between chemical energy and heat.

Often a 'flowing' energy form is named after its source, both in daily life and in our textbook: solar energy, wind energy, hydro energy, nuclear energy. So in a particular context energy may have two or more names: nuclear energy and electrical energy, solar energy and heat, etc.

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- kinetic energy: 'the energy that is used up for moving' (for instance: 'in a car 20% of the energy from petrol is used (up) as kinetic energy'). In the same way heat and light may be interpreted: the energy used (up) for heating, lighting. In discussions it is hard to decide whether energy is named by students correctly after its form or, as described here, after its use. In both ways the same term is used, but for different ideas.
- energy loss: 'that is the part of the supplied energy that is spoiled or that doesn't flow into the device'. That may be correct in some situations (for example chimney losses of a stove), but students appeared to use it in situations of transformation losses as well. For example if a power plant has an efficiency of 40%, 60% of the electric energy is said to be 'spoiled' underway to the consumers. Another example is the solar cell. Students said the efficiency can be improved by enlarging the area of the cell, so that more radiation can be received.
- energy conservation: 'the sum of the part of the supplied energy that is used up and the loss equals 100%'.

Students using the generation-transportation-consumption framework can hardly make sense of expressions like 'something has energy'. Many students deny that something may have energy, because if energy is generated (comes to existence) it is transported and used up immediately. Some students said that something may have energy as long as it is supplied with energy.

It appeared that quite often expressions from the textbook and the teacher could be easily interpreted within this framework, or they even seemed to use it themselves. Many quantitative tasks could be done well with it, so not surprisingly the teachers had little idea of the underlying conceptual problems.

energy consumption and production

In this interpreting framework some appliances are seen as consumers and sources at the same time. Knowing that heat, light and 'movement' are energy forms, students can make use of this framework. Important appliances, in this respect, are bulbs, engines and power plants. A bulb consumes electrical energy and produces light (radiation energy). A power plant consumes fuel (energy) and produces electrical energy. In this way 'transformation' can get a meaningful interpretation. This also applies to 'conservation', if the idea of transformation losses is included. For that purpose, a flow-picture of some quasi-material substance, being the energy conserved, can be added to this framework. The curriculum reinforces this framework by making extensive use of 'energy flow diagrams' as shown in figure 1.

fig. 1. Energy flow diagram from the 'Energy' textbook.

This interpreting framework is related to the former. A difference is that the energy form being used up, is seen now as an outflow. For example: in a drilling machine one outflow is the energy used up for doing the drilling job, the other is the heat loss due to friction and resistance. Again this framework is very difficult to detect as it can hardly be distinguished from a correct way of saying, i.e. that 'electrical energy is transformed into kinetic energy and heat'. It becomes apparent, however, in the case of

heating a room. Students say the heat flow out of a room, in winter-time being held at constant temperature, does not equal the inflow as the job of heating has to be done too.
From this interpreting framework, forms of energy that should be attributed to an object like kinetic energy, chemical energy, internal energy, are necessarily treated as energy flows. As a result, for chemical energy the energy flow and the material flow are confused; with respect to motion, kinetic energy and work done by friction are mixed up, etc. So such energy forms cannot get a fruitful meaning within this framework. In fact, analysis of the teaching materials reveal that also this framework is often stimulated unintentionally in the curriculum.

energy storage
This interpreting framework originates from statements like:
- in fuel energy is stored because the sun puts in energy, when the plants, the fuel originates from, were growing, and we can get energy out of it;
- in a rechargeable battery energy is being stored when the battery is loaded;
- the energy needed to increase the speed of a car 'comes free' when the car collides with a tree.

Now the focus is not on continuing processes but on processes that come to an end (changes in temperature, speed, phase, height). Discussing such processes, students first argued that energy may be used up for a forward proces, while the reverse process could generate energy. This made them finally conclude that thus energy is stored during processes in which e.g. temperature, speed or height increase.

5 Reflection on the 'interpreting frameworks'.

A careful analysis of the development of these frameworks in students' discussions showed this to occur in a certain order, as the above. From our description given, it is clear that the 'practical' context of instruction, regarding energy consumption and supply, plays an important role in the development. Some of the students already used the consumption and production framework in the first 'Energy' lesson and attained the energy storage framework soon after. Others, however, did not develop the 'storage' framework until the 'Work and Energy' unit. This suggests this order to be autonomous to a certain extent. It appeared from the transcriptions that the group members made considerable progress in their concept development towards a more scientific energy concept. However most of them did not reach the 'storage' framework required at the end of the 'Energy' unit. This may explain that the progress in qualitative understanding during the 'Work and Energy' unit was unsatisfactory, even though students learned reasonably to manipulate quantitatively with the formalism.

Because of the suggested importance of the order in the interpreting frameworks, it was decided to use them to devise 'instructional frameworks', for the revision of the energy teaching sequence. In the revised practice-oriented unit, now called 'Energy supply', the 'storage' framework is the endpoint, in the revised 'Work and Energy' unit, a further developed scientific energy concept is aimed at. From the above it will be clear that the 'instructional frameworks' have to be used very carefully, to avoid that concepts are introduced that can get no proper interpretation in the framework under consideration.
A major starting point chosen is the distinction between forms of energy

exchange ('energy flows') like heat, electrical energy, radiation energy and work between (thermodynamic) systems, and forms of energy that can be attributed to systems, like internal energy, kinetic energy, potential energy. This distinction can be found (among others) in Duit (1984).

Taking the above into account a strategy for the introduction of the energy concept has been designed, which consists of four 'instructional frameworks'.

We assume that at the start of the teaching sequence, most students have already developed a 'source-and-consumption' framework. However, both to be sure and for for the sake of repetition, this frame is explicitly used for the introduction of specific heat of combustion, with burning fuel as a heat-source, and of specific heat, using hot water from 'city heating systems' as a heat-source.

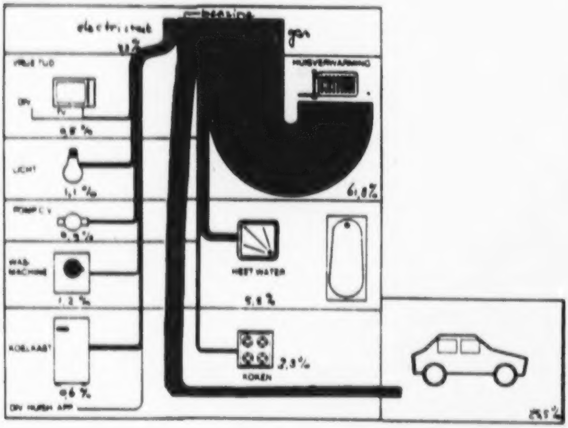
elektriciteit
benzine
gas
HUISVERWARMING
LICHT
1,1 %
WAS-MACHINE
1,2 %
KOELKAST
0,6 %
6,8%
HEET WATER
KOKEN
2,3 %

fig. 2. A drawing from the unit 'Energy Supply', illustrating the use of the 'source-transportation-consumption' instructional framework.

Subsequently, we focus on appliancies, which use and/or produce heat, electrical energy, light or work, one energy form being consumed and another being produced. Wilst talking about energy going into and coming out of an appliance, a conserved quasi-material flow-picture is introduced. Then the efficiency of an appliance is mentioned.

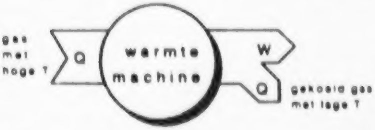
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fig. 3. A drawing from the unit 'Energy Supply', illustrating the use of the 'consumption-production' instructional framework.

From the conservation rule, situations in which the outflow does not equal the inflow are problematized. The argument that the outflow can be delayed leads to the concept of energy storage and the introduction of 'forms of storage energy', such as: internal, kinetic, gravitational, chemical energy, for which formulae are introduced. Systems of energy storage and energy 'generation' like flywheels in a car, reservoirs and hydropower plants, storage batteries and generators are dealt with.

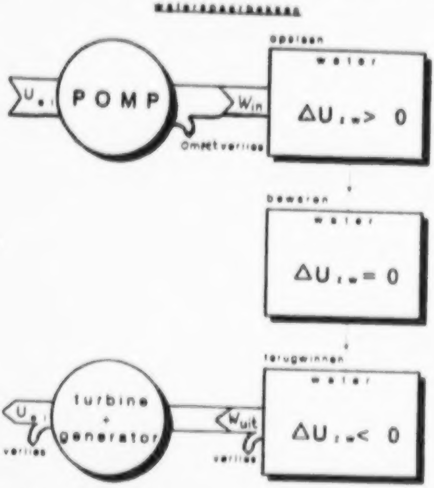

fig 4. A drawing from the unit 'Energy Supply' illustrating the use of the 'storage' instructional framework.

Energy conservation is expressed in a formula for these systems: the sum of the energy flows in and out equals the change in stored energy. This completes the concept development in the practice-oriented unit 'Energy Supply' (Poorthuis e.a. 1988a). The discipline-oriented unit 'Work and Energy' (Poorthuis e.a. 1988b) starts with the same conservation formula, but extends its applications to new systems, such as: a falling stone, a pendulum, Joule apparatus etc. Using idealised situations, the relations and concepts introduced in 'Energy supply' are first sharpened and extended, and subsequently applied again to realistic problems. So it is tried to bridge the transition from the 'practical' meaning at the end the first unit, to an extended and more precise scientific meaning at the end of the second unit.

6 Final comments

Five teachers have used the revised energy curriculum. Data from questionnaires and audiotapes have been collected and are being evaluated. Preliminary results seem to indicate that the strategy, based on the instructional frameworks, give students a better grasp of the subject. In transcriptions of discussions, the development and use of the successive frameworks can be observed. However, the teaching sequence appeared to be hard to follow for the teachers. Apparently, the instruction of the teachers has been insufficient. This remains a main problem to be solved in the future.

Without doubt, a further analysis of the data will show that the curriculum should be improved in many details. There is an increasing evidence, however, that the presented strategy enables a stepwise development of an energy concept, from every day meanings to a useful scientific meaning, for many students.

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ENERGY EDUCATION FOR NON-SCIENCE MAJORS AND TEACHERS

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This paper presents an overview of our experiences in energy education for non-science majors and teachers during the past two decades. Both of us (JRP and WHR) are university physicists, and entered the area of energy education in 1973, the time of the Arab oil embargo. We became interested in energy education for several reasons: 1) the importance of the energy and environment problem to our society, 2) the obvious relevance of physics, and science and mathematics generally, to understanding the role of energy in our society, and 3) our perception of the energy topic as an excellent theme for teaching introductory physics. Our experiences in energy education are uniformly positive, testify to the importance of education on this topic, and confirm our perception of the energy topic as an excellent pedagogical vehicle for teaching the fundamental principles of physics. We find considerable student interest in energy and our society even though general societal interest in energy has waned.

Our experience in energy education has been primarily within a course titled "Energy and Society" that is offered for non-science majors each term at Miami University. The course is taught in a large section having some 150 students, as well as to a small section of some 20 students in the Honors Program at Miami University. The text for the course is Energy: Principles, Problems, Alternatives, Third Edition (1984), by one of us (JRP). Other relevant experience is the organizing of energy institute/workshop programs for elementary and high school teachers, and service by one of us (WHR) in directing the U.S. Department of Energy's Institute/Workshop Program for teachers from 1976-78. In addition, we would like to bring to conference participants' attention an interesting summer institute for college/university teachers which focused on development of the Breeder Reactor, and which was held at Argonne National Laboratory's western site in Idaho Falls, Idaho, U.S.A.

The Energy and Society course at Miami University begins with a summary of the current U.S. and world energy use pattern and estimates of available energy resources. The introductory material also includes consideration of basic mechanics and what might be called the "physical basis for energy". A large part of the course then consists of detailed considerations of the various energy resources (fossil fuels, nuclear fission, nuclear fusion, solar energy, conservation, etc.), the current and developing technologies for utilizing these resources, and the associated environmental impact. Areas of basic physics (electricity, magnetism, thermodynamics, electromagnetic radiation, and nuclear physics) are introduced throughout this portion of the course, in conjunction with energy technologies which are closely related to a particular area of physics. For example, basic electricity and magnetism are introduced along with the examination of the workings of an electric power plant. Thus, an electric power plant serves as a real-life illustration of electricity and magnetism.

From an energy standpoint what emerges in the course is essentially a comparison of the status, benefits, and risks of various energy technologies. The course is analogous in this regard to familiar courses in comparative religion and comparative literature. One obvious and important comparison which arises is between the environmental costs and risks associated with coal-burning and nuclear electric plants. We believe this comparative viewpoint to be pertinent to the emphasis within this conference on "risk education". We feel that Miami students leaving the Energy and Society course are keenly aware of the societal risks associated with all current technologies and the reality that there is no "risk-free" technology currently available. Few students can be expected to remember the magnitude or mathematical statement of the nuclear power risk presented by the Rasmussen Report; most will learn and remember, however, the alternative costs associated with fossil fuel power plants, and recognize the true comparative nature of the nuclear power debate.

We have offered the Energy and Society course under alternative conditions on several occasions. In recent years we have presented the course as a seminar for students within the Miami University Honors Program. This effort has been quite successful, and is ongoing. Earlier, in the late 1970's, with funding from the U.S. Department of Energy (previously the Energy Research and Development Administration) we offered one-week summer institutes for elementary and high school teachers. Such summer programs for teachers were quite successful and were very highly acclaimed across the United States. Despite their effectiveness, however, funding for these teacher institutes was discontinued in the early 1980's by the Department of Energy with the apparent easing of the "energy crisis". We believe this decision by the Department of Energy to have been a short-sighted one, and suggest that U.S. participants at this Conference consider a recommendation to the Department to reinstitute funding for this worthwhile program.

We plan to continue our efforts at Miami University in the area of energy education, and are anxious to incorporate material and ideas from this international conference in courses and an expected revision of the text. We would be grateful to conference participants for any suggestions regarding such material, particularly in the area of risk analysis.

RENEWABLE AND UNRENEWABLE ENERGIES: TALKING THEMSELVES

Benito Laiz Castro
Bacchilerato Dominguez Ortiz
Madrid, Spain

1. - Introducing Energy ideas, in both scientific and social meaning, but before having gathered the students ideas, on a "brain storm session, about energy."
2. - Encouraging the crucial importance of the Energy question for the future of the planet and the human race.
3. - Giving some general views about different kinds of energies referred to their renewable and unrenewable characters.
4. - Asking for each student to choose one type of energy or similar (proton, neutron, conservation...) and become him/herself the character to be played afterwards.
5. - Supplying them with enough bibliography to learn his/her role according to the energy he/she chosed.
6. - Suggesting them to prepare his/her own energy disguise appropiated to their own energy.
7. - Checking the different texts about different energies and coordinating by the teacher in a certain way and correcting the mistakes, not the texts.
8. - Adding some "pepper and salt", if necessary, to make it more atractive.
9. - Rehearsing once or twice if we want to perform for a big group or other students.
10. - Asking them to make a special scenery for the public role-play, if it is the case.
11. - Putting the play on.
12. - A collaborator group will prepare music, microphone, loudspeakers, casette, video camera and so on for complete happy performance with energetic drinks and dancing in an energetic bar. (Bright coloured drinks made of food dye, water and sugar, for example.)
13. - Another scientific elements like some diaporamas about new energies (solar-eolic for example) and some scientific references can be introduced by the teacher.

In any case, if you try, you will see the results!

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MICROCOMPUTER IN TEACHING ABOUT THE CONSERVATION OF ENERGY

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I. INTRODUCTION

In recent years some new trends in physics teaching can be recognized which deserve a thorough analysis. The main topics include elementary, secondary and university schools misconceptions, the meaning of concept names and the physics of everyday life.

Without a doubt, energy is the single, most important physical concept in all of science. The importance of the concept of energy lies in fact, that various form of energy within an isolated system can be transformed one into another without a change in the total amount of energy. That is, in any physical process, energy is conserved.

At the same time the concept of energy is extremely difficult to understand for 14-15 years old students. Student's understanding of the physicist's meaning of the term energy is affected by the fact that it has various connotations in everyday language. The young children associate the term energy mostly with human activity; some of them however consider energy as an ingredient or byproduct of a situation, but only very rarely as a conserved quantity [1-7]. Their intuitive understanding of energy expressed by the statements: "Eat a good meal and you will have a lot of energy", or "A person who has a great deal of energy can do a large amount of work" correspond however quite closely to those that the physicists would make: "Energy is the capacity to do work".

As a matter of fact a clear understanding of energy and an appreciation of its importance was not fully realized until 1847, when Herman von Helmholz (1821-1894) enunciated the general law regarding energy, but he called it "die Erhaltung der Kraft" - the law of force conservation. The Scottish physicist W.J.M. Rankine (1820-1872), civil engineer from

Glasgow, was the first who used the term "energy" in the law of conservation of energy.

The etymology of the word "energy" is very clear. The Greek word "wergon" meant the same as our word "work". At an early stage Greeks dropped their "w" and "wergon" bacame "ergon". Aristotle (384-322) used the word "en-erg-eia", because it meant the property of things which were "in work" or at work. (-eia is an ending that makes an abstract concept out of something concrete, just like inertia is the abstract concept of inert things)

As we see - from the very beginning - the concept of energy was closely associated with the concept of work. And nowadays, energy is looked on as a possibility of doing work, a potentiality more than an actuality.

Different ways of teaching of the concept of energy have been suggested. One way is to introduce a large number of names of energy forms and describe how energy can be converted from one form to another. This way, however is rather difficult for the young students, usually already having their own misconceptions about energy, and because we are very fast arriving at the problem of rigorous definition of energy forms and the question arises:"should we consider energy forms or energy carriers?" [8]. From our didactical practice we have found advantageous to follow another way, suggested by Thomsen, who proposed to introduce first two main energy forms - kinetic and potential energy (in fact accesible from everyday observations for everyone), and consider all other energy forms as names for different combinations of those two [9]. It seems to us that using microcomputer, we can significantly increase didactical value of Thomsen's suggestion, by direct measurements of the potential and kinetic energy values in suitable experiments and quantitative studies how these energies transform into each other (in order to "rediscover" of the energy conservation principle).

II. COMPUTER AIDED EXPERIMENTS

Computer aided education has been recognized for a number of years [10-14], but is only now beginning to be fully exploited. Especially, the use of microcomputer as an universal, didactical laboratory aid is starting to grow rapidly in the last years [15-26]. Recently, in the paper on: "Using Computers in Teaching Physics" the authors J.M. Wilson and E.F. Redish are saying: "Computers can revolutionize not only the way we teach physics but also what physics we teach" [27].

To couple the polish school type computer, provided with Z80 microprocessor, with different laboratory instruments, a simple and cheap interface have been constructed. With appropriate BASIC and machine code software we can carry out the data acquisition and reduction or demonstration of many school physics experiments, such as: air track experiments, Galileo experiments (motion of falling body and pendulum motion), acoustic experiments (including mesurements of sound velocity in different materials, Doppler frequency shift and demonstration of acoustic field phenomena), motion investigations by supersonic detector, radioactivity measurements and so on. Designing all these computer aided laboratory experiments we are having in mind the possibility of illuminating topics that are often difficult to students (or secondary school pupils), when presented in more traditional ways [28].

We would like to present now two simple computer aided laboratory experiments, which we believe, are particularly suitable to introduce the energy concept, and to emphasize the most important (fundamental) element of the traditional physics course - the conservation of energy principle.

II.1.GALILEO EXPERIMENT

When Galileo attacked the problem of motion of falling bodies, he sought to find a simple relationship connecting quantities he could measure. By dropping objects of different weights from high places (though probably not from the Tower of Pisa as legend would have it), Galileo quickly concluded that the weight of an object was not a factor in its falling motion. Galileo began his quantitative experiments by rolling balls down inclined planes. In this way he was able to "dilute" the effect (gravity) that produced the motion of a freely falling body whose motion was too rapid for him to make accurate measurements. Because he lacked a clock to measure the short time intervals involved he invented a water clock for the purpose.

It appears to us that we can teach a great deal of physics and the scientific methods as well, following Galileo reasoning and repeating his famous "free fall" experiment just on the class room table, having a handy microcomputer. Besides the computer, hardware involved in this experiment includes electromagnet, which can hold steel ball (from the ball bearing), piezoelectric microphone, placed on the table and rather simple interface, which can in the given instant release the ball and record electric pulse from the microphone, when free falling ball hits table surface. The height of the free fall can be varied with accuracy of 0.1 mm using suitable height setting micrometer. The general view of the measuring device we can see in Fig.1.

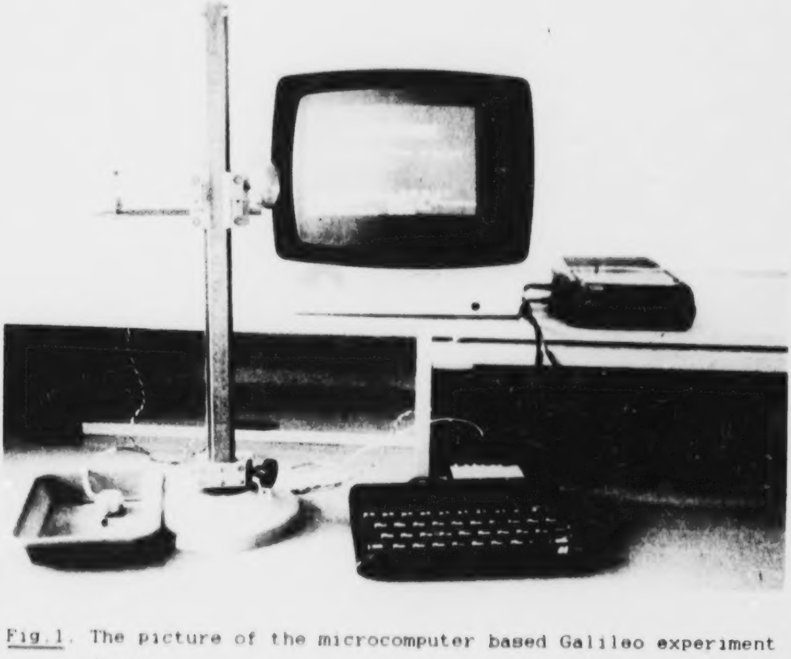

Fig.1. The picture of the microcomputer based Galileo experiment device

It is interesting to note that using internal computer clock as a time reference, and with some care, it is possible in this experiment to measure time with accuracy better than 0.1 milisecond, that is more than three orders of magnitude better than Galileo did, using his very slow water clock,

Having such a convenient measuring instrument we can easily rediscover the Galileo's free falling bodies law. All the measured values of height, time and final velocity are in the real time displayed on the screen during the experiment and futhermore we are gathering all of these data in the memory of the microcomputer. The above results we are using for detailed analysis. We are plotting the mean values of the experimental points t as a function of height h in a few coordinates systems and searching for a proper mathematical relation between them first. Using the mathematical least-squares fitting method we are deriving the parabolic dependence between the experimental quantities h and t i.e. $h = g\ t^2$, and from this fit we are obtaining the constant g - the earth acceleration value.

But now, we are taking the advantage of the accumulated data for checking the energy conservation principle for the free falling body or assuming this principle, derive the well known formula for the kinetic energy $E_{kin} = 1/2mv^2$ directly from the experimental values of h and $\vec{v}_{final}$. Taking into account theexperimental errors, for the same mass of body we are obtaining equality between the products $(g \cdot h)$ and $(v^2/2)$ with the accuracy better than 0.5 %; see Table below.

h [cm]	$\bar{t}$ [ms]	$\bar{v}$ [cm/s]	$v^2/2$ [m^2/s^2]	gh [m^2/s^2]
10	142.53	140.32	98.44	98.1
15	174.75	171.67	147.35	147.15
20	201.87	198.14	196.29	196.20
25	225.81	221.42	245.13	245.25
30	247.41	242.51	294.05	294.30
35	267.28	261.89	342.93	343.35

By the way, because we are dealing with so great accuracy of time interval measurements we can try to show to the students what the mathematical relation describing the instantaneous velocity $v_i = \lim_{\Delta t \to 0} \Delta x / \Delta t$ meant.

II.2.OSCILLATION

The next devices with interesting possibility of quantitative investigation of the energy conservation princile with aid of microcomputer are different oscillating systems, e.g. a weight moving up and down on a spring, a small cart swinging in the appropriate curved track, an oscillating steel blade mounted in a chuck, or the best known pendulum motion system [16,20]. In all these systems "the work is stored", so their mechanical energy continually changes between potential and kinetic energy and would be constant if there were no friction.

Hardware used in this investigations* consist of SPECTRUM type microcomputer with interface capable to drive the low power supersonic transducer, record signal from corresponding supersonic microphone and at the same time sense switch closure, which begins and ends the data recording run. With aid of the machine code computer program it is possible to measure running position of the moving bodies with accuracy of about 1mm, taking about 700 independent measurements per second and store up to 20 thousand of data points for single run. Duration of the experiment is limited essentialy by the available computer memory to store instantaneous positions.

In all studied oscillating systems lightweight sonic transducer is attached directly to the moving body. Necessary in this case thin signal carrying wires are integrated into oscillation system (in the pendulum - used as the suspension) or mounted in a way not disturbing the moving system itself.

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*In this experimental setup we use continuous ultrasonic wave at frequency of 40 kHz produced by the transducer driven from the interface. Relative phase of the signal recorded by microphone depends upon the instantaneous distance between transducer and microphone, i.e.- phase is varying by 2π when the microphone is moving by one wavelength.
The computer program samples a signal from the microphone and computes the running phase with the resolution of $1/8\ \lambda$, i.e. about 1 mm of distance in our case. Elementary phase computing cycle determining maximum possible time resolution lasts 352 μs. The above program produces also "on line" graph of the instantaneous positions and records results in the memory at time intervals multiple of 352 μs.

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Actually, the measured quantity in these experiments is the straight distance between the microphone and ultrasonic transmitter. Therefore for the oscillating systems where movement takes place on the circular path (pendulum, oscillating steel blade etc.) measured values have to be converted into time, x, y coordinates. But, with the aid of computing power at hand, this can be easily done with simple program in BASIC, taking into account geometry of the experimental setup. With some more calculations, the measured instantaneous positions can be converted into the values of instantaneous velocity and acceleration.

We can start with presentation of results and their discussion now. It is possible to display on the monitor screen the values of the instantaneous potential and kinetic energy and show, that their sum stays constant (neglecting some insignificant experimental errors) through the oscillation period, but due to the natural damping process it will slowly decrease in subsequent oscillation periods.

III. CONCLUDING REMARKS

It seems to us that some didactical advantages of presented here quantitative approach to the question of energy are following:

1) The experiments attract students attention to the better understanding of the well known everyday phenomena such as free fall or bodies oscillating.
   Energy, as a directly measured quantity is a concept which can be more easily grasped by young students mind.
   This may be especially true in case of the expession for the kinetic energy ($E_{kin} = 1/2 \; m \; v^2$), which is usually introduced only theoreticaly by the formulas manipulation [28].
2) Due to the use of microcomputer, fast experimental data processing along with capability of the immediate and clear display enables some inquiring students to "rediscover" energy conservation principle from the real observations.
3) The above computer aided experiments may acquaint students with the scientific method of investigations and help to stress the role of the appropriate experiment in process of verification of the physical theory.

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THE NEW YORK STATE STUDENT ENERGY RESEARCH COMPETITION

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Each year science teachers in the state are notified of the competition and invited to encourage students to compete for funding. Of course, many teacher and students are aware of the competition and start to prepare for it well in advance. A few students submit projects which build on their work of previous years.

The competition is open to individuals or teams of two or three. Three page project proposals are submitted at the start of the school year. These outline the project and each project team may request funding to purchase supplies and equipment not easily available in the schools. Up to $500 is available for each team. Not every team requests the full amount. It is not uncommon for teams to request less than $100 and in a few cases, no money has been requested. There is no provision for cost overruns!

A panel of judges from the Energy Authority/Energy Office and educators rate the projects. About 100 projects are selected during this first round. The students work on their projects during the school year. Students are required to file interim progress reports so that potential problems may be detected early. In May the students bring their projects to Albany for the Competition. Travel expenses for the students and their advisors are paid by the Authority.

During the first day in Albany, students set up their projects in the convention center in Rockefeller Plaza. On the second day, each project is rated by six judges. The judging panels include scientists, engineers, educators, and staff members from the sponsoring offices. Generally, the judges first do an informal survey of all the projects to acquire an understanding scope and level of competition. The students then present their projects to each of the six judges.

The judges rate each project on a weighted scale covering such aspects of the projects as: research, understanding, organization, and presentation. Judges are provided with specific instructions for rating the projects. Winners are determined on the basis of the highest combined scores. During the judging, the student's teachers are taken on tours and participate in workshops. The students are on their own. We have served as judges for a number of years and have noted a steady increase in the quality of the projects. The task of selecting the best has become more difficult.

On the final day of the competition a formal awards ceremony is conducted. Prizes for the first three projects in each category are medallions and saving bonds of $100 -- $300. Provision is made for the awarding of duplicate prizes in case of ties and special awards if warranted. In addition, the students select projects for a set of peer awards which consist of savings bonds and plaques.

The organizers expend a great deal of effort to make the trip to Albany a pleasant experience for the students and teachers. They are housed in nice motels, well fed and entertained at a pizza/disc jockey party. Each participant receives a Round I award certificate and a t-shirt with the competition logo. An important goal of the sponsors is to make the event a positive experience for all involved.

A survey by the of the winning project titles related to alternative energy since 1983 shows three categories which have attracted the most attention by students: improving efficiency, solar energy, and biologically based energy resources. This information in summarized in the table below.

CLASSIFICATION	1983	1984	1985	1986	1987	1988	1989	TOTAL
CHEMICAL	0	1	1	1	0	3	1	7
EFFICIENCY	4	5	5	7	5	6	3	35
BIOMASS	4	1	4	2	3	3	2	19
SOLAR	5	6	5	2	4	1	6	29
WIND	2	1	0	1	1	0	0	5
OTHER	0	0	0	1	1	2	1	5

Energy Categories of Winning Projects

Of course, some projects, such as solar collectors designed to improve efficiency of collection, better windmills, and resource recovery overlap categories making classification difficult and the scheme somewhat arbitrary. Biomass includes ethanol production and resource recovery.

EVALUATION

In 1987, Mary Jean Frank of the Energy Authority, conducted a survey of more than 620 students who had participated in the Competition. About 30% of the advisors sent surveys responded. This section contains some of the results of that survey.

Nearly three-quarters of the students contacted were attending four year schools. Rensselaer Polytechnic Institute, MIT, and Cornell lead the list as most frequently attended schools. Eighty-three percent of the students reported that their participation in the Competition had "some" to "strong" effect in encouraging them to learn more about energy research and development. The survey indicated that the sense of accomplishment in having their work recognized and the opportunity to meet students from other parts of the state were the most rewarding aspects of their participation in the Competition. Actually carrying out their project taught them the most about taught them the most about energy research and development. About half indicated a continuing interest in the field.

Teachers responding to the survey indicated that students, teachers and periodicals were the most frequent sources for ideas for projects. Most of the students preferred to work in teams. The amount of time devoted to the projects varied a great deal. The table is a summary of the times reported.

100 +	hours	17%
81 - 100	hours	6%
61 - 80	hours	9%
41 - 60	hours	25%
21 - 40	hours	25%

CONCLUSION

The New York State Student Energy Competition is sp[illegible]ed by the state's Energy Office and The New York State Energy Research and Development Authority. The mission of the Authority is to develop safe, dependable, renewable, and economic energy sources and conservation technologies for New York. To this end the Authority sponsors third-party energy research, development and demonstration projects. Most of the funding comes from an assessment on sales of electricity and gas in the state.

A staff member suggested a student energy competition as a new and innovative approach to fulfilling the Authority's mission. The competition is designed to:

- Arouse the interest of students, teachers, parents, and administrators in New York's energy problems;
- Get students to develop innovative solutions to these problems;
- Spark student interest energy research, development and demonstration;
- Give students experience with research in competing for limited funding to carry out their research.

Response to a survey conducted by Mary Jean Frank of the Authority and the writers experience as judges at the competition indicate that these aims are being met.

In the past eight years hundreds of secondary students in New York State have taken advantage of the opportunities presented by the Student Energy Research Competition. There are many indications that the goals listed above have been met. Over the years the writers have noted a steady increase in the quality of the projects. The Competition provides a useful model for others with similar goals. For additional information contact:

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Albany, New York 1223
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Sources

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SOLAR AND WIND ENERGY SIMULATOR

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Solar energy and wind energy are interesting topics in physics education because they are familiar in our life and because they are investigated as those of future energy sources.

Main problems to utilize these large amount but dilute energy are how to collect, convert, store and consume them efficiently, in other words, to develop optimum systems for any purpose at each region of the world. Taking into account of this situation, we think that we can add some abundance and functionality to energy education, where energy forms and their conversion phenomena have been concentrated on mechanical and thermal ones in dynamics and thermo-dynamics.

The solar and wind energy simulator is a computer simulation program for individual experimentation and study, small group work or classroom competition. Our goal is to make a "investigating environment" that includes several tools for students to observe and evaluate these energy and to make simulation experiments designed by themselves.

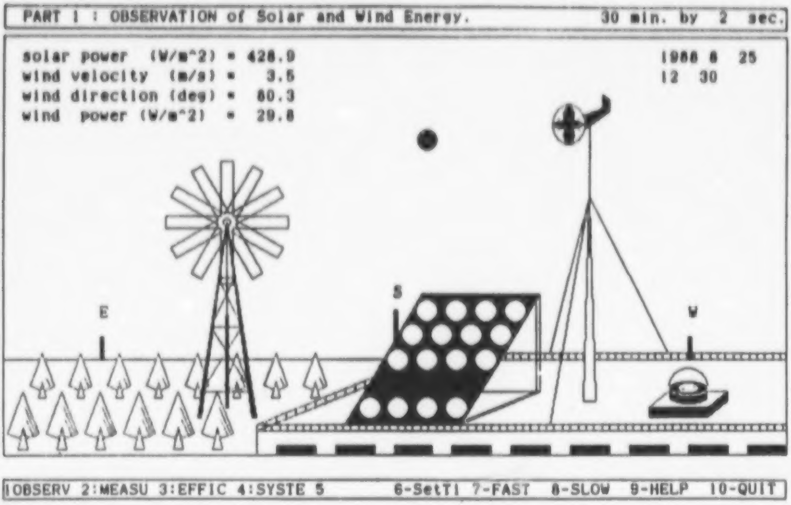
Structure of the software

The solar and wind energy simulator works with the real data. These were measured in every minutes and recorded in the form of mean or sum at every 30 minutes in Ube College of Technology (North Latitude 34) for six years. These data include the items as follows.

solar energy density for horizontal surface ---------- (WH/m^2),
ibid. for tilted surface (typically 34 deg. to ground)-(WH/m^2),
wind velocity ------------------------------------- (m/s),
wind direction ------------------------------------ (deg),
wind energy density for wind facing surface ---------- (WH/m^2),
electric energy converted by a solar cell with 0.565 m --(WH),
ibid. by a wind turbine with two blades of 1.8 m diameter -(WH).

Using these data, the insolation on arbitrary tilted surface and the generated electric energy from solar cell panels and/or wind turbines are calculated for conditions selected or decided by the user, such as the energy conversion efficiency and the tilt angle and the area of the collecting surface.

Starting the program, students are invited to just the present hour, day and month of last year. The solar and wind data together with the approximate position of the sun are displayed in the screen as shown in Fig. 1. This is the "Observing" part. The time proceeds and the data will change. They can change the



```
PART 1 : OBSERVATION of Solar and Wind Energy.            30 min. by  2  sec.

solar power  (W/m^2) = 428.9                              1988 8  25
wind velocity  (m/s) =   3.5                              12  30
wind direction (deg) =  80.3
wind  power (W/m^2)  =  29.8
```

E
S
W
1OBSERV 2:MEASU 3:EFFIC 4:SYSTE 5
6-SetTI 7-FAST 8-SLOW 9-HELP 10-QUIT

Figure 1 Display of "Observing" Part by PC9801 (640x400).

speed of the clock and the working time throughout the software. They are requested to examine and evaluate the available solar and/or wind energy as a energy resource and to design a useful system that converts these energy to electricity using solar cells and/or wind turbines.

The program has the four parts that have common time to proceed and can be transferred between them at any time by a Function Key, as follows.

F1 -- PART1 Observation of Solar and Wind Energy
F2 -- PART2 Measurement and Analysis of S and W Energy
F3 -- PART3 Efficiency of the Energy Conversion
F4 -- PART4 Design of Energy Conversion Systems
F6 -- To change the starting time of experiment
F7 -- To make faster scanning of data
F8 -- To make slower scanning of data
F9 -- To see the Help Documents and Graphics
F10 - To quit the program

The "Measuring" part provides students a graphic tool that presents the energy data as they want. They can select several options such as the item to be measured,the area and the tilt angle of collecting surface, the scale of x-axis (period) and y-axis, the width of viewport, and the symbol and color of plotting. This means that they must have any idea how to grasp

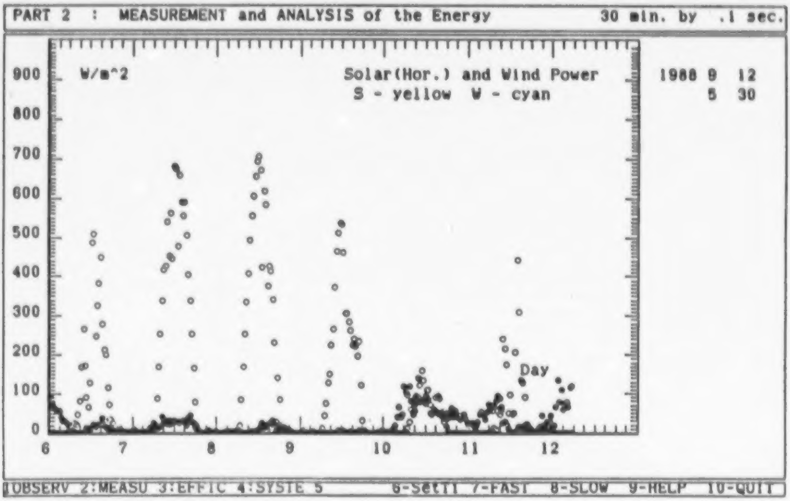
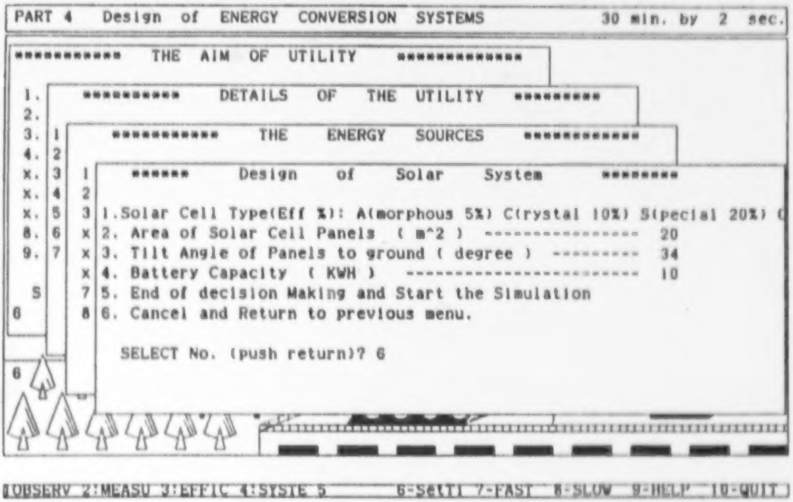

PART 2 : MEASUREMENT and ANALYSIS of the Energy
30 min. by .1 sec.
W/m^2
Solar(Hor.) and Wind Power
S - yellow W - cyan
1988 9 12
5 30
900
800
700
600
500
400
300
200
100
0
6
7
8
9
10
11
12
Day
1OBSERV 2:MEASU 3:EFFIC 4:SYSTE 5
6-SetTI 7-FAST 8-SLOW 9-HELP 10-QUIT

Figure 2. Display of "Measuring" Part, an example.

and evaluate the amount and variation of the ambient energy. They can also draw the energy variations averaged daily or monthly. Fig. 2 shows an example of the display.

The "Efficiency" part is designed to treat the energy conversion efficiency. In the present version of the software, two experimental results are shown. One is the conversion efficiency of solar radiation to electric energy by a crystalline Si solar panel as a function of input solar power. The other is that of wind kinetic energy to electric energy by a two blade wind turbine with a D.C. generator as a function of the wind velocity.

In the "System Designing" part, four steps of sub-menu will be presented to students as shown in Fig 3. A energy conversion system is designed by their selections or decision makings and a simulation experiment for this system will begin using the time series of real data described above. During the simulation, students observe how their system works as shown in Fig. 4.
How much electric energy is generated and how much is consumed effectively ?
How much is wasted as overflow energy in storage battery and/or how much is the shortage for the energy demand in their system?
How does the situation vary depending on the season in a year?
Some students will modify their system design and others will go back to "Measuring" or "Efficiency" part to study more about the



```
PART 4  Design  of  ENERGY  CONVERSION  SYSTEMS            30 min. by  2  sec.
*********** THE AIM OF UTILITY *************
1.  ********** DETAILS OF THE UTILITY *********
2.
3. 1  *********** THE ENERGY SOURCES ************
4. 2
x. 3 1  ****** Design of Solar System ********
x. 4 2
x. 5 3 1.Solar Cell Type(Eff %): A(morphous 5%) C(rystal 10%) S(pecial 20%) (
8. 6 x 2. Area of Solar Cell Panels  ( m^2 ) ---------------- 20
9. 7 x 3. Tilt Angle of Panels to ground ( degree ) --------- 34
     x 4. Battery Capacity  ( KWH ) ---------------------- 10
 5   7 5. End of decision Making and Start the Simulation
6    8 6. Cancel and Return to previous menu.

         SELECT No. (push return)? 6
6

1OBSERV 2:MEASU 3:EFFIC 4:SYSTE 5       6=SetTI 7-FAST 8-SLOW 9=HELP 10-QUIT
```

Figure 3. The sub-menu series in "System Designing" part.

characteristics of the ambient energy.

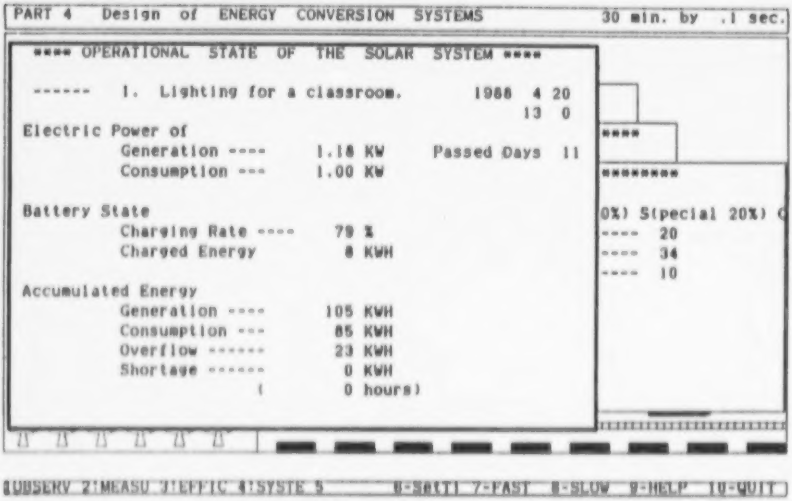
Educational merit and future improvement

In 1986, the International Conference of Physics Education was held in Japan for the first time. In this Conference, G. Marx[11] has said that really important ideas of science are not the elements of scientific knowledge but are deeper ones, that are concepts such as Observation, Measurement, Experiment, Frame of reference,---,Handling energy/information,---,Loss/efficiency,------,Risk/decision and so on. He has also said that these orientational skills are surely needful for all young people.

Using the computer, the abundance and complexity of nature can be work as a good teacher for students to learn such concepts (to say nothing of scientists). However most important will be how to use a software and how to improve it for the purpose and method of education.

Although our experience with students is not sufficient yet, we have many important suggestions.

The direct discussion or the communication through letter between students or between teacher and student will be necessary and very effective in using the educational software. In our software, the student's aim, method and results of his experiment



```
PART 4   Design  of  ENERGY  CONVERSION  SYSTEMS           30 min. by  .1 sec.

 **** OPERATIONAL  STATE  OF  THE  SOLAR  SYSTEM ****

 ------   1.  Lighting for a classroom.        1988  4 20
                                                     13  0
Electric Power of
          Generation ----     1.18 KW     Passed Days  11
          Consumption ---     1.00 KW

Battery State
          Charging Rate ----    79 %
          Charged Energy         8 KWH

Accumulated Energy
          Generation ----      105 KWH
          Consumption ---       85 KWH
          Overflow ------       23 KWH
          Shortage ------        0 KWH
                        (        0 hours)
```

****
****
0%) S(pecial 20%) C
---- 20
---- 34
---- 10
1OBSERV 2:MEASU 3:EFFIC 4:SYSTE 5
6-SetTI 7-FAST 8-SLOW 9-HELP 10-QUIT

Figure 4 Simulation Experiment in Part 4.

are desired to be recorded in a diskette and to be used by students and also teachers.

Some students will want to modify or to add new functions to the program. We are interested in the method of Shell Program introduced by J.S. Risley[2] in North Carolina State University (U.S.A.) that offers students the opportunity to write the few lines of code. Using this method in our software, students can realize their idea, for examples, to make the averaging, the frequency distribution and the correlation of the data. Another method is a set of tools that simplify tasks frequently used with a large amount of efforts for students. The Maryland University Project in Physics Educational Technology (MUPPET)[3] has developed the data-input tools and the graphic tools. The latter allows students to plot data by issuing a single command and/or to control the graphic environment with commands for scaling, clipping, and adjustment to screen coordinates. The programming language they selected is PASCAL. We have also made the graphic tools just like those of MUPPET, using a structured BASIC language. The other tools we developed are the menu tools that can be used by single command to display two kinds of menu at any position in graphics with optional number of items. One is the menu to select a item number and the other to select items and input numerical data or letters. They are convenient to make and to control the program flow. We think that the sophisticated student can write his program using these tools.

To increase user friendliness, the help menu to open useful documents and interesting graphics is necessary to full up. In the present version of our software, a few is installed including the block diagrams of experimental setup, the elevation and direction of the Sun (for inputted Latitude and Date), solar power on arbitrary tilted surface and the graphics showing the principle of solar cell.

Other obvious improvements are to introduce a economical evaluation of the systems designed by students and to use the data of the solar and wind energy in other regions of the world. The former will be rather easy but the latter difficult. One solution is to make the time series data of them by a stochastic model using the seasonal variation and diurnal variation of the mean values, their standard deviation and correlation, if they are available.

Finally, We hope that students will learn about the ambient energy and its phenomena and that they will acquire desirable skills such as observing, analyzing and decision making skills.

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. International Herald Tribune.

SOLAR ENERGY EXPERIMENTS

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Measurement of the Power Density from the Sun

This is a very simple, calorimetric setup for the measurement of the power density received from the Sun. The setup is depicted in Figure 1. We use two identical rectangular aluminum blocks [1] (2 x 2.5 x 4 cm). A hole is drilled through each block, and a resistor [2] (10Ω, 2W) is embedded in the hole. The block is mounted on a styrofoam base, and both blocks are mounted on a solid strip, from which they are isolated by their bases. A second hole in each block is filled with plasticine and a thermometer [3] is pushed into it, so that is in good thermal contact with the aluminium block. The upper face of each block is blackened using soot from a candle.

Directly above each block there is a screen [5] made of a rectangular piece of styrofoam, with a removable part directly above the block. A thin rod [4] is mounted on the solid strip holding the blocks, perpendicular to it, and is used to ensure that radiation will hit the black surface at normal incidence.

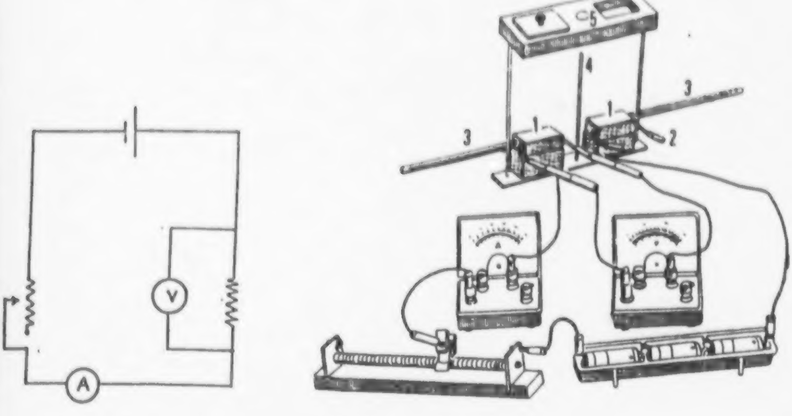

Figure 1

The measurement procedure proceeds as follows:

a. One of the covers is removed, exposing the surface under it to radiation from the Sun. Students watch the temperature rise as measured by the thermometer. Typically, the temperature rise observed is 6-8°C. Once the temperature is steady, dynamic equilibrium has been reached: the energy absorbed during any [illegible] interval at the surface equals the energy lost by the blocks by all loss mechanisms. (The main loss mechanisms are radiation and convection by air at the surface of the block. However, none of the details matter for the purpose of the experiment.)

b. The second block is shaded from the sun by the cover above it. The resistor embedded in the block is connected through (three 1.5V batteries are appropriate) and the electric current causes heating of the block. By changing the current with the rheostat, and noting the temperature of the block, one can easily reach a situation where the temperature of the block is equal to that of the other block, and remains constant. Hence, steady state is established here too. One now records the voltage across the resistor (V) and the current through it (I). The loss mechanisms in both blocks are identical, so the rates of energy loss are the same for both blocks. Therefore, the power inputs into both blocks are also equal.

c. The equality of both input powers yields a direct measurement of the solar radiation power hitting the surface. We have: $P = VI$ for the power dissipated in the shaded block, and this equals the power absorbed from the Sun by the other block. The irradiance (power per unit area) is therefore $E = VI/A$ where A is the area of the exposed surface.

It can be seen that the measurement does not require information about mass, specific heat, resistance, heating rate, and/or cooling rate. The only data required is the area of a rectangle, the current through and the voltage across a resistor and two temperature readings.

As an educational bonus the students study and understand a fundamental concept used widely in physics, chemistry and biology: *the concept of steady state* or *dynamic equilibrium*. A detailed description and some experimental results can be found in a previous article[1].

A Model of a Solar Pond

Solar ponds are an effective means for the collection and long term storage of solar energy for power production[2-4]. The operation principle of the pond is simple and very elegant.

A salinity gradient and consequently a density gradient are present in the pond. Solar radiation is absorbed, and partially reaches the bottom of the pond. In a pond with uniform salinity, convection in the vertical direction will result and thus the heat will be transferred back to the atmosphere. In the solar pond, the density gradient prevents the vertical convection, and energy is accumulated in the lower layers of the pond.

When operated properly, the energy may be stored for weeks and months, because the only losses are by heat conduction, and water is a poor heat conductor.

The energy can be extracted by recycling the hot water from the low layers through a heat exchanger.

Our model consists of two transparent plastic boxes. The dimensions of each box are: 30cm [W], 40cm [L], 40cm [H]. The bottom and the walls are insulated with 5cm thick styrofoam boards. A 5cm wide styrofoam strip is cut out from one of the walls and three

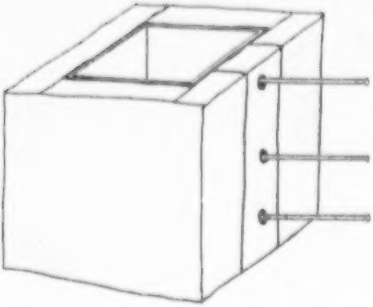

Figure 2

holes (D=20mm) are drilled through the strip and the wall at the top, the middle and the bottom. Thermometers mounted on suitable rubber stoppers are located in each hole (Fig. 2).

The ponds are mounted in an open place, free of shadows. One of the ponds is labelled "EXPERIMENTAL" and the other one "CONTROL".

The solutions contain rock salt (NaCl) and a small amount of Copper-Sulfate ($CuSO_4 . 5H_2O$). The function of the Copper-Sulfate is to create a colour gradient commensurate with the salinity gradient. As it turns out, it is also useful in preventing the growth of algae.

The "CONTOL" pond is filled with 48 liters of a uniform solution containing 7200 grams of rock and salt and 22.5 grams of Coper-Sulfate.

The "EXPERIMENTAL" pond is filled with 10 layers of decreasing salt concentrations (bottom-highest concentration). The composition of the layers is given in the Table The solutions are poured into the pond very slowly, on a floating board, in order to prevent the layers from mixing.

Measurements: The temperatures of the two ponds are recorded by the students several times per day during 10 days, and are plotted on a graph. The gradient in colour in the experimental pond and the difference between the ponds can be observed by removing the styrofoam strip.

Layer	Volume (l)	Salt (g)	$CuSO_4$ (g)
1	4.8	1440	4.5
2	4.8	1280	4.0
3	4.8	1120	3.5
4	4.8	960	3.0
5	4.8	800	2.5
6	4.8	640	2.0
7	4.8	480	1.5
8	4.8	320	1.0
9	4.8	160	0.5
10	4.8	0	0
Total	48.0	7200	22.5

The temperatures in the different layers of the "CONTROL" pond are uniform and students can observe that the heat absorbed during the day is lost during the night. On the other hand the temperature differences between layers in the "EXPERIMENTAL" pond increase daily until a steady state equlibrium is achieved. in an experiment conducted in Rehovot, Israel, we recorded 18°C to 22°C (at noon, in April) in the upper layer, and 55°C in the lower layer, after seven sunny days.

In the experiment performed in Balaton during the workshop, we recorded 13°C in the upper layer and 18°C in the lower layer after only two days of cloudy skies.

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Appendix

A series of short experiments are performed in class, as a demonstration of the physical principles involved in the operation of the solar pond.

1) ***Density differences between salt solutions and water.*** Two test tubes are half filled with water. Two test tubes are half filled with colored, concentrated salt solution. Pour water slowly with a pipette over the salt solution. Pour salt solution slowly with a pipette over the water. Record your findings (Fig. 3.)

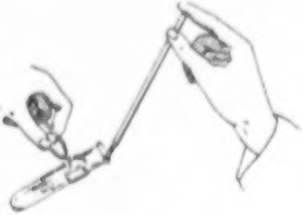


Figure 3

2) *Is water a good heat conductor?* Prepare a test tube filled with ice. Heat the upper part of the tube with a bunsen flame until the water boils. Record your findings (Fig. 4). Hold a test tube filled with ice. Heat the lower part of the tube with a bunsen flame until the water boils. Record your findings (Fig. 5).

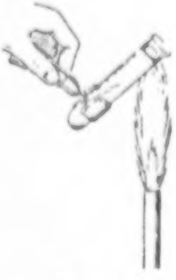


Figure 4

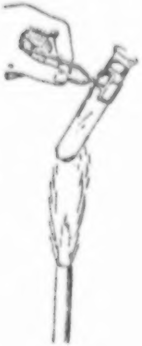


Figure 5

3) *Convection currents.* Fill a test tube with concentrated salt solution. Put 2 or 3 small crystals of Potassium-Permanganate ($KMnO_4$) into the solution. Heat the bottom of the tube gently. Record your findings (Fig. 6).

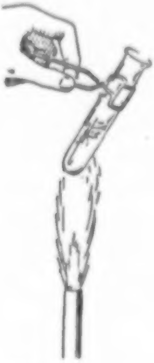


Figure 6

4) ***Heat conduction in a solution with layers of different densities.*** Fill half a test tube with concentrated salt solution. Pour water slowly with a pipette over the salt solution. Put 2 or 3 small crystals of Potassium-Permanganate ($KMnO_4$) into the test tube. Heat the bottom of the tube gently. Record your findings (Fig. 7).

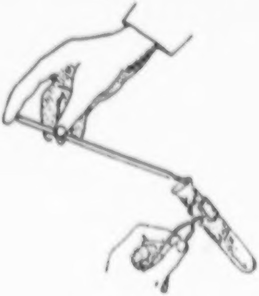


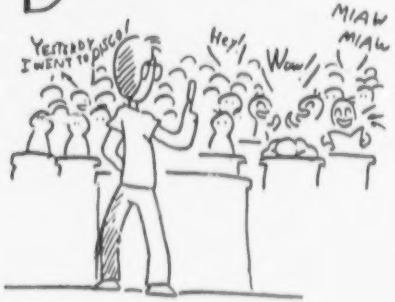
Figure 7

NUCLEAR EDUCATION

We have 45~50 students in a class.

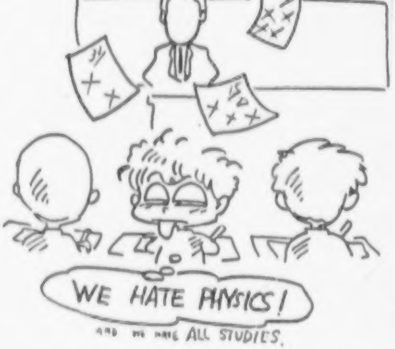
"A highschool physics class in Japan"

1


YESTERDAY I WENT TO DISCO!
Hey!
Wow!
MIAW MIAW

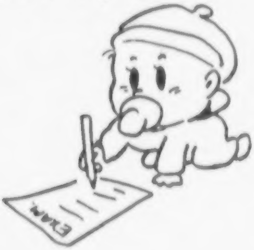
2 "EXAMINATION HELL"

STUDIES IN HIGHSCHOOL ARE ONLY FOR THE UNIVERSITY ENTRANCE EXAM.


WE HATE PHYSICS!
AND WE HATE ALL STUDIES.

3

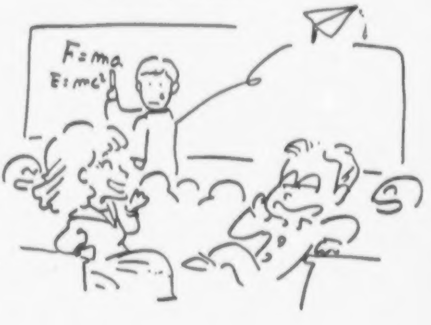
EXAMS. EXAMS. EXAMS... FROM THEIR EARLIEST CHILDHOOD!



4

IN JAPAN MANY STUDENTS HAVE LOST THEIR PURPOSE IN STUDYING.

THEY HAVE NO CHANCE TO ENJOY PHYSICS.



RADIATION AND OURSELVES

Tae Ryu
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Tokyo 102, Japan

I. Physics Classes of High School in Japan

First, I would like to describe briefly physics classes in Japanese high schools using illustrations by Mr. Kouji Okumura, a physics teacher (Fig. 1). Mr. Okumura is a member of the Aichi and Gifu Physics Circle, which is one of the most active groups of high school physics teachers(1)(2). This group is developing a new physics course in which students are able to enjoy doing low-cost physics experiments. However, the membership of such groups is quite low, and most physics teachers seldom teach physics in an enjoyable way. The number of students who take physics courses in high schools has been decreasing and now stands at less than 30 % of the present high-school age generation (94 % of which go to high school in Japan). As a rule, physics teachers and professors prefer teaching physics to future physics department students and not to non-science students. However, physics students make up only 0.15 percent of their generation in Japan (Fig. 2). As the influence of physics on society increases with the development of technology, we have the responsibility of making the study of science relevant and enjoyable to all citizens.

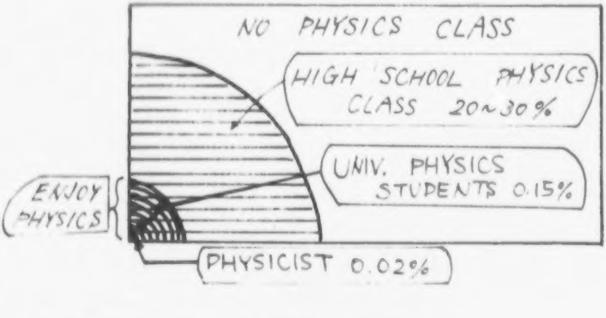
NO PHYSICS CLASS
HIGH SCHOOL PHYSICS CLASS 20~30%
UNIV. PHYSICS STUDENTS 0.15%
ENJOY PHYSICS
PHYSICIST 0.02%

Fig. 2 High school students in Japan

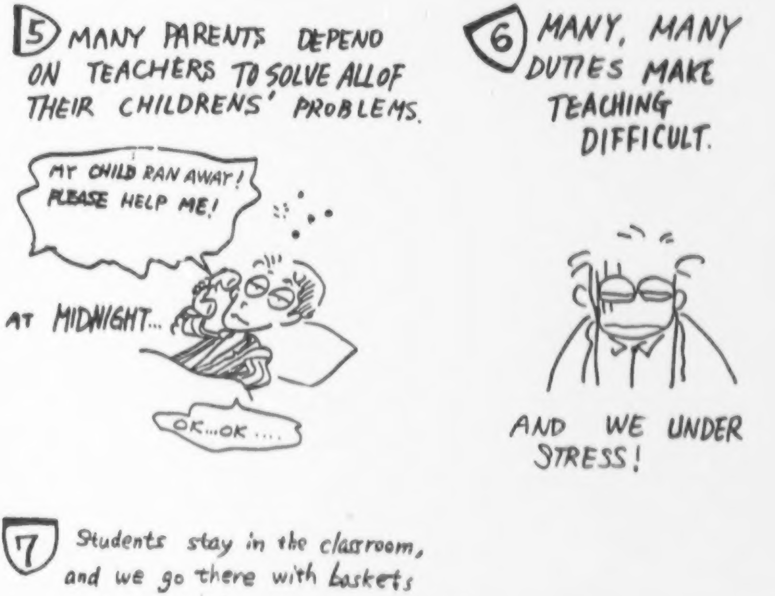
5 MANY PARENTS DEPEND ON TEACHERS TO SOLVE ALL OF THEIR CHILDRENS' PROBLEMS.
MY CHILD RAN AWAY! PLEASE HELP ME!
AT MIDNIGHT...
OK...OK....
6 MANY, MANY DUTIES MAKE TEACHING DIFFICULT.
AND WE UNDER STRESS!
7 Students stay in the classroom, and we go there with baskets containing "low-cost experimental apparatus."
8 OUR EXPERIMENTS ONLY HELP US!
I FIND, PHYSICS ENJOYABLE!
AND THEY ENJOY PHYSICS.

Figure 1 (by K.Okamura)

II. Radioactivity and Physics Education

One hundred years ago no one knew of radioactivity. However, today all people on earth are exposed to the danger of radiation from a possible explosion of nuclear weapons and leakage from power plants. In Japan, the number of nuclear power stations has increased rapidly from only one in 1965 to thirty-five in 1988 (Fig. 3), an increase accompanied by debates between the proponents and the opponents of nuclear power. As a rule, in these debates, the government and the electric companies emphasize the safety and the economic benefits of nuclear power, and citizen groups on the other side the dangers. I think we Japanese people are irrationally afraid of radioactivity, because of Hiroshima and Nagasaki. We lost relatives and friends because of atomic bomb not only during the war but also in the last few decades through leukemia (Fig. 4).

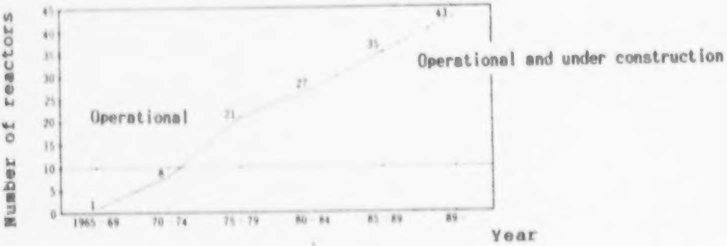

Fig. 3 The number of reactors of nuclear power plants in Japan

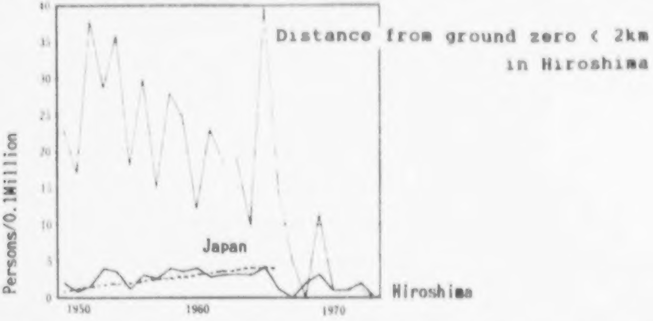

Fig. 4 The number of persons dead by leukemia per 0.1 million

However, most people have no scientific knowledge of radioactivity, although the general interest in radioactivity and radiation has increased since the Chernobyl accident of 1986. Yet Japan, unlike Europe and America, offers its students little chance to study radiation in science courses (Fig. 5). Even students in university physics departments have little knowledge of radioactivity in its relation to daily life and social problems.
I believe that it is our duty as physicists in order to keep people healthy and to preserve the environment, to teach everyone what radioactivity is and how it affects the human body.

Fig. 5 An example of pages on radiation from a physics text-book

I have been teaching radioactivity to non-science students in universities and junior colleges for fifteen years. (Japanese university students, like American university students, have both major and minor subjects.) My "Physics and Society" course at Sophia University is quite popular among students, and they are especially fond of group discussions. From the comments and opinions of students, I have come to understand the thinking and interests of non-science students, especially the ways in which their thinking and interests differ from those of scientists. I wrote "Radiation and Ourselves", a booklet (Fig. 6,7) for non-science students which was published this February and used it as a textbook in my "Physics and Society" course. Last year, I made a series of NHK T.V. programs titled "The Structure of Matter" for high school students in Japan. It consisted of a series of five 20-

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minute lectures - "Structure of Matter" "Electrons", "Structure of Atoms", "Radiation" and "Nuclear Fission" in all of which computer graphics are used. I have edited many video tapes of TV programs for use as teaching aids in the course. The content of such teaching materials is quite different from that of traditional physics - little mathematics, many illustrations, and an emphasis on relevance and application to society. I would like to report on my experience teaching this course, using it as an example of a course which non-science students prefer to traditional ones.

1. The intangibility of radiation
   1.1 Sense and radiation
   1.2 Atmosphere and radiation
   1.3 Humanity and radiation
2. Spontaneous emission of radiation
   2.1 The nucleus as a building block of matter
   2.2 Sponteneous decay of the nucleus
   2.3 Random and uncontrolled emissions from the nucleus
3. Interaction of matter and radiation
   3.1 Ionization by radiation
   3.2 Alpha-ray and heavy nucleus
   3.3 Beta-ray and light nucleus
4. The use of radiation in hospitals
   4.1 Diagnosis and radiation
   4.2 Treatment and radiation
   4.3 The effects of radiation on the human body

Fig. 6 The table of contents of "Radiation and Ourselves"

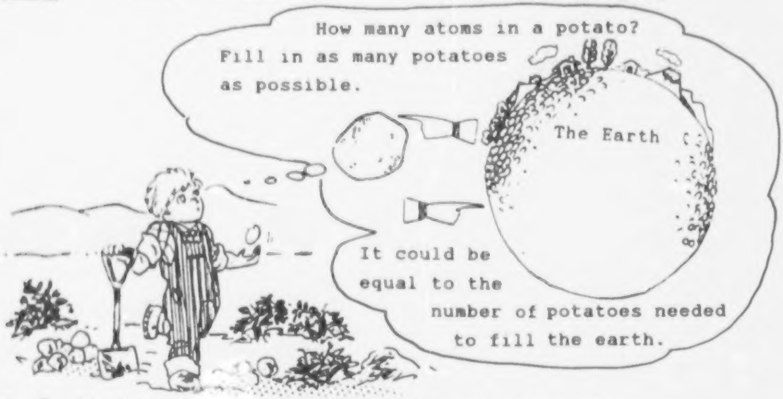
How many atoms in a potato?
Fill in as many potatoes as possible.
The Earth
It could be equal to the number of potatoes needed to fill the earth.

Fig. 7 An illustration from "Radiation and Ourselves"

III. Teaching "Radiation" in the Course "Physics and Society"

The course is a general science education elective for non-science students at Sophia University in Tokyo and consists of one 95-minute lesson per week for one year (26 weeks). The topics of the course are changed from year to year, in order to give attention to current issues. However, five main topics - energy, radioactivity, astronomy, computers, and bio-technology, have been included for several years.

The aims of the course this spring term were:

1. To encourage students to understand radiation and its effect on the human body and humanity;
2. To encourage students to have an interest in science and to study it by themselves throughout their lives;
3. To encourage students to understand the relevance of science to society and to discuss their ideas freely with others.

About 140 students have enrolled in the course this spring and 120 students submitted final reports (20 dropped out). These students come from many non-science departments in the four faculties of law, economics, literature, and foreign language, and their grades range from freshman to senior. At the beginning of the course, more than half of the students are not interested in physics (Fig. 8), and their knowledge of physics ranges quite widely from a lower secondary school level to that of a physics department student.

	Studied physics in high school	Didn't study physics in high school	Sum
Interest in physics	27	9	36
No interest	23	18	41
No answer	3	9	12
Total	53	36	89

Fig.8 Students' interest in physics at the beginning of the course, April, 1987

After Chernobyl, radioactivity became the main topic which students wanted to study (Fig. 9). However, more than half of the students couldn't answer the question "What is radioactivity ?" at the beginning of the course (Fig. 10), and radiation is even more difficult for them to explain (Fig. 11, 12). At the end of the first term, 30 % of the students still could not explain radioactivity correctly (Fig. 13). These students had poor attendance records and they dropped out of the course.

Topics	Number of students
Radioactivity	17
Astronomy	13
Energy, Energy resources	4
Light	3
Computers	3
Atomic physics	2
Elementary particles	2
Gravity	2
Relativity	2

Contents	Number of students
Daily life phenomena	15
Relevance to society	12
Scientific thinking	6
New topics related to life	6
Practical aspects of science	4
Relevance to citizens	4
Others	7

Fig. 9 Topics in physics which students wanted to study at the beginning of the course, April, 1987

Correct answers	
Emission power of radiation	3
Matter emitting radiation	1
Ambiguous answers	
Disintegrated atom	2
Matter emitted by nucle. explo.	6
Hazard for humanity	24

Wrong answers	
Radiation	8
Nuclear power	4
No answer	
I don't know	28
No answer	26

Fig. 10 Answers to the question, "What is radioactivity ?"

Is it different from radioactivity ?	5
Light with radioactivity	3
Light	2
Radioactive ray	2
Short wavelength ultra-violet	1
Generated by explosion of atom	2
Generated by nuclear fission and fusion	2
I don't know and no answer	69

Fig. 11 "What is radiation ?"

X-ray	51
γ-ray	32
α-ray	27
β-ray	22
Ultra-violet	4
Ultra-red	3
Neutron	1
Uranium-253	1
No answer	32

Fig. 12 Kinds of radiation

April 1987 (Total number = 102)

	Correct answers	Ambiguous and wrong answers	No answer
Radioactivity	71	12	18
Radiation	78	5	18
Nucleus	78	5	18
Nuclear energy	87	3	11

Fig. 13 Number of students who answered questions at the end of the spring term, July, 1987 (Total=101)

The syllabus and the teaching aids used in the course this spring term are shown in Fig. 14 and the content in Fig. 15. In the first and second lessons, students are given the motivation to study "Physics and Society". After they have studied scientific knowledge in several lessons, they used it to discuss social problems which they chose themselves. This year during the last lesson of the spring term, I distributed copies of the paper "Use of Solar Energy" by Professor Isao Oshida. Profesor Oshida was the first president of the Solar Energy Society of Japan and wanted to write science textbooks for children with me. Unfortunately, he died last year. He said that all of the world's non-renewable energy resources would be able to supply only two generations of humanity. However, he noted, the earth receives plenty of renewable energy from the sun (Fig. 16). "Plants use solar energy effectively, we must learn from plants" he said. After each lesson, each student must answer questions and write their comments and opinions. They also have to submit reports of experiments and a final report on "Physics and Society" with a note on their impressions of the textbook. Almost of all students wrote that both this course and the textbooks were useful to them, and about two thirds of the students wrote that we must consider changing our lifestyle in order to ensure the peace for people all over the world (Fig. 17). The number of students is too large for participation in laboratory experiments or individual research experiments in physics, and the lack of assistants and facilities keeps me very busy. However, I am happy to know that students are eager to study by themselves and enjoy debates using their new scientific knowledge. I believe that everybody should study science for future of society. We must find a way to motivate our students and we must create suitable teaching materials for them.

The 1st lesson: Radiation and Atmosphere
Video: Ozone Hole and Greenhouse Effect
Student Experiment: Spectrum of Light

The 2nd lesson: Sensing Radiation
Video: American Soldiers and Nuclear Test in Bikini
Demonstration: Radiation and a GM-Counter

The 3rd lesson: Radiation and Nucleus
Video: Madam Curie
Video: Structure of Matter, Structure of Atom

The 4th lesson: Half-life
Student Experiment: Half-life Using Dice

The 5th lesson: Radiation and Matter
Video: Radiation
Demonstration: α,β,γ-rays, a Cloud Chamber and a GM-Counter
16mm Film: Diagnosis Using New Technology

The 6th lesson: Nuclear Fission and Power Stations
Video: Nuclear Fission
Lecture: Talk by an Expert from an Electric Company

The 7th lesson: Nuclear Fusion, Hydrogen Bomb and Renewal Energy
Video: Nuclear Fusion
List: Reference Books for Group Discussion

The 8th-10th lessons: 1) Nuclear Power and Energy in the Future
2) Nuclear Weapon and the Reduction of Armament
Group Discussion: 1) 5 Groups A - E and 2) 5 Groups F - J

The 11th lesson: Nuclear Power and Energy in Future
Plenary Reports: 5 Groups A - E
Discussion
The 12th lesson: Nuclear Weapons and the Reduction of Armaments
Plenary Reports: 5 Groups F - J
Discussion

Fig. 14 The program of teaching "Radiation & Ourselves" in 1989

I. Motivation to Study

Practical Reasons Students must want (Knowledge)

1. to protect their environment (Spectrum, Light and Matter)
2. to protect their health ...tection, Politics)

II. Study of Science

Concepts (Works of Scientists)

3. Matter, Atom, Nucleus, Electron, Proton and Neutron
   Radioactivity, Radiation (Rutherford, Curies)
4. Half-life, Probability of Decay, Statistical Prediction
5. α,β,γ, Ionization, Absorption
6. Nuclear Fission, Energy and Mass, Chain Reaction
   (Hahn, Meitner, Einstein, Fermi)
7. Nuclear Fusion, Solar Energy, Renewable Energy

III. Application to Issues

Student Topics Chosen by Themselves

8.-10. Group Discussion, 11.,12. Plenary Discussion

e.g. 1) Peaceful Uses of Nuclear Power
   Debate about Nuclear Power Stations
   Proponents and Opponents, Location of Nuclear Power Stations
   Waste, Safety of workers and public
   Radioactive Contamination of Environment and Foods
   Comparison with Other Energy Sources,
   Greenhouse Effect of Carbone Deoxide
   Nuclear Fusion, Renewable Energy
   Economic, Politics, Quality of life

2) Military Use of Nuclear Power
   Debate about nuclear armaments
   History of the Development of Nuclear Weapons
   A Nuclear Deterrent, Nuclear Tests, The Role of IAEA
   Nuclear Club, Proliferation, Nuclear Winter, Terrorism
   The Responsibility of the Scientist
   Three Non-Nuclear Principles (of not manufacturing,
   not possesing, and not introducing nuclear weapons in Japan)
   Nuclear Umbrella, SDI
   Munitions Industry and Economics in U.S.A.
   Economic Crisis and Disarmament in U.S.S.R.
   International Economics and Politics, Waste of Resources
   Total Elimination of Nuclear Weapons

Fig. 15 Contents of the Course "Radiation and Ourselves" in 1989

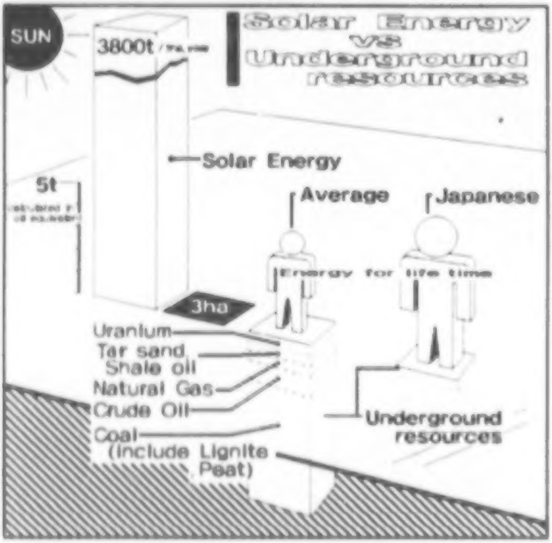
Solar Energy
vs
Underground
resources
SUN
3800t
5t
Solar Energy
Average
Japanese
Energy for life time
3ha
Uranium
Tar sand
Shale oil
Natural Gas
Crude Oil
Coal
(include Lignite
Peat)
Underground
resources

Fig.16 Solar Energy vs Underground Resources by I.Oshida & Y.Tanaka

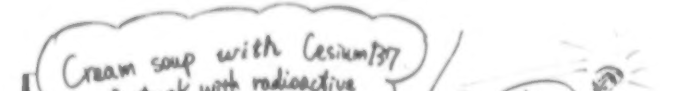
Cream soup with Cesium137
Beaf steak with radioactive carrots
Vegetables grown with agricultural chemicals
Acid Rain
MENU
only Bread, Milk
and the sun, and the flowers ....
Future
Our children will live in ....

Fig. 17 Student's Idea by Mrs Chiyoko Yuki

References

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3) Chikazumi, S. etc., 1989 'Buturi'(high school physics textbooks in Japanese) Tokyo Shoseki etc. (Japan)

4) Japanese Ministry of Education, 1977,1989, The Course of Study - National Curriculum for Lower Secondary Schools & Upper Secondary Schools in Japan (Japan)

5) Nuffield Physics, 1966,1977 & Advanced Physics 1971,1986 (U.K.)

6) Project Physics, 1970,1981 (U.S.A.)

7) Lauterbach, R. and Mikelskis, H. 1981 'Teaching the Issue of Nuclear Power'(IPN), Nuclear Physics, Nuclear Power (Hungary)

8) PLON 1984 (Netherland)

9) Fizika 1984 (Hungary)

10) Science in Society 1980 & SATIS 1986 (U.K.)

11) Nuffield Co-ordinated Science Physics 1988 (U.K.)

ENERGY EDUCATION IN JAPAN
TRAINING ON ATOMIC ENERGY, AIMED AT TEACHERS

Masami Hirose, Yunichi Iiri, Kazutoshi Osaka, Toshikazu Shibata
Tokyo, Japan

I. Introduction

Japan is a country of scarce natural resources. Therefore, it has to depend on import for the most part of its needed energy resources such as coals, natural gas and so on. However, it consumes a lot of energy due to the vigorous production activities and to maintain its people's standard of living, and its energy consumption is the second largest in the world.

Its task to obtain energy resources securely is executed successfully at present, and Japan is rather uninterested in the energy consumption issues. And the level of consumption still remains in incremental tendency. Once it fails to secure the resources, on the other hand, it has a tendency to easily fall into various social confusions. The oil crisis of 1972 is a good example of the tendency, when the people's lives were shaken badly to the extent to be called "panic". Under those circumstances, many emotional discussions took place to form the public opinions at the time, when was the first time energy saving and new energy development surfaced as key issues. Thus, Japan seems to solve the energy consumption related issues at the last moment.

One of the reasons of the aforesaid conditions may be resulted from the lack of systematic and continuing education regarding energy issues at the school sites. In Japan, a country of poor natural resources, energy education based on a systematic curriculum from a global point of view should be planned and planted.

It is also essential to educate the people about the way of thinking and viewpoint in connection with energy planning for the future, the way of balancing-securing natural resources and consumption and the ways of energy saving for it, and so on. That is; taking into consideration of natural resources, environment or development of scientific technology with global eyes, it shall not be emotionally one or the other type of education, but we have to build up science education which allows people to judge issues from multilateral and comprehensive point of view.

After the oil crisis, the objectives of our energy policy are to decrease the dependency on oil and to focus on developing an alternative energy, specially the development of atomic power generation. As a result, approximately 30% of electric power generated in Japan at present, i.e. one third of electricity, is generated by atomic power generation. Even in Japan, however, the movement concerning pros and cons of atomic power generation has become a big issue.

II. Education on atomic power in Japanese schools

Six years of elementary school and three years of junior high-school are compulsory in Japan. In addition, more than 90% of the students go to high schools, therefore under the present circumstances high school may be called equivalent to compulsory education.

A course of study which is legally set up by the Ministry of Education has control over the contents which should be taught within the school education system. Therefore, seeing the course of study would reveal clearly the contents of the school education.

The first course of study of 1948 has been revised or corrected about ten year intervals since then. In the year of 1963, description about atomic power appeared mainly in text books of physics and chemistry for regular high-schools and of general atomic engineering and radiation chemistry for technical high-school. At the same time a part of knowledge concerning atomic power was taken into the courses of science and social science for junior high-schools. The contents or the guidance regarding atomic power so far have not been systematic and organized enough, and it is not adequate for the complete educational system.

Let's track down the trace of the progress to know the actual circumstances about peaceful uses of atomic power in Japan. In 1955, the Atomic Energy Act was constituted, and research and development being limited to peaceful uses based on three principal rules of independency, democracy and opening to the public was commenced. In 1957, JRR-1 nuclear reactor for research use in Japan Atomic Energy Research Institute reached the critical point, and thus the first atomic fire was lighted in Japan.

The first national nuclear reactor reached the critical point in 1962. In 1965 the Tokai Power Plant, the first Japanese industrial power plant, was constructed. Since then utilization of atomic power generation developed steadily. In addition, energy policy which emphasized lessening of rate of dependency on oil and development of the alternative energy after the first and the second oil crises have pushed the development of atomic power generation up further to the extent of its depending on atomic power generation by one third of its electricity produced in 1986.

III. Activities of Multidisciplinary-Educational-Forum

Multidisciplinary-Educational-Forum, an education and research organization, was established in 1976 by Seiji Kaya, who was one of the leaders in science education in Japan, and others.

Wide range of knowledge from multiple and comprehensive point of views extended over present specified physics, chemistry, biology, geography, social science and so on is required to solve multidisciplinary issues such as resources, energy, environment, foods and population. At present and in the future, science and technology and social problems are complicated and will be more complicated, and it seems that the education responding to these issues will be required to shift the point of view to the great extent.

At the same time it is important to give multidisciplinary education to children in school age who will support the next generation. However, information presented about these multidisciplinary issues through newspapers and other media, being reflected diversified values and anxiety towards the future, is quite confused one.

Taking these conditions into consideration, we, Multidisciplinary-Educational-Forum, provide occassions for fair discussion through research and training about how to pick up and handle in the educational site these essential issues which Japan and the world would not be able to avoid so that in future the children may think, judge and act according to theire right selection about these issues at their own discretion form the comprehensive point of view.

As the concrete outcome, we design, plan, and undertake a training session "Nuclear Reactor Experiment for High-school Teachers" and "Field Trip to Atomic Power Plant" and so on.

These will become a desirable milestone in energy education system and will build foundation for opinions based on an objective discussion.

This experimental training session on nuclear reactor is aimed for writers of textbooks, mainly highschool science teachers of physics and chemistry, and teachers of other courses. We consider it anepochmaking event as all the participant teachers will load nuclear reactor with fuel by themselves and experiment and observe while experiencing the operation of the nuclear reactor, and through the action they will look for a new direction of research and study centered on atomic power as well as reaching to the essence of science education.

1. Organization and activities of experimental traning session on reactor

(1) Schedule and number of participants:

- Each session consists of three nights and four days.
- Number of training sessions held so far 8 and the number of participants 150.

(2) Production of textbook

Research workers of Kinki University and Atomic Energy Institute organize project teams in each field and produce textbooks. They tried to let the readers understand without using numerical formulas.

(3) Main themes of the lecture and the contents of the experiment include the followings:

1) Details of the lecture at the training session
    (i) Outline of nuclear reactor and its safety
    (ii) Physics of nuclear reactor

2) Details of experiment at the training session
    (i) The critical point experiment
    (ii) Measurement of reactivity
    (iii) Measurement of neutron flux distribution and estimation of reactor power
    (iv) Activation analysis of trace elements
    (v) Measurement of dose equivalent

By learning these contents of lectures and experiment items, first they are able to obtain basic knowledge on nuclear reactor, then the outline of nuclear reactor safety, and understand principles and rules of this physical phenomenon. In addition we believe that this experimential training session, in which they actually measure and seek for the results at site through the aforesaid experiments, will result in forming of scientific background and understanding.

We use UTR-KINKI nuclear reactor for research, which uses enriched uranium and the maximum output is 1W. Among all the experimental items, the critical experiment which is to add fuel gradually while estimating the critical mass from the inversion doubling degree to fuel loading calculated by using count value of neutron moves, trainees, and they all seemed to get quite nervous when the critical point was achieved. Such experimental training session aimed at school teachers may be the first trial in the world.

2 Field trip to an atomic power plant and s

We visit, three times a year, facilities of Atomic Energy Research Institute in Tokaimura or an atomic power plant for industrial use or other places as a field trip. Teachers from various fields such as science, social science and homemaking come around, make a discussion on atomic power and deepen the knowledge of atomic power.

IV. Conclusion

As mentioned above, we have continuously held the outlined training sessions, field trips etc. since 1986. Specially, as for experimental training session on nuclear reactor, eight sessions were opened from 1986 to today. The total number of participant trainees in the sessions is nearly 150, and they are persons from various fields including science teachers of high-school, science teachers of junior high-school, teachers of social science, homemaking and so on, and faculty members of natural science and social science in teachers's training colleges.

We consider that attending the training sessions, experiencing at the site from loading fuel to operation of nuclear reactor and measuring various radiations will give them scientifically correct knowledge and understanding about atomic power.

Concerning issues such as atomic power generation, we hope that as the first step an objective discussions, whether it is pro or con, may be made. Of course it is not possibly done in a day, but making an effort towards it is, we believe, the first step of the correct understanding of atomic power, and we would like to continue the effort.

Nuclear physics is the totally unknown and inexperienced field to and for teachers, and we think our effort is an important trial to consider the essence of science education in the rapidly developing society of science and technology.

NUCLEAR CONCEPTS

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Radiation, it is all around us from natural and technological sources. The characteristics of radiation, its interactions and effects are not typically covered in high school and most college curriculum. By learning more about radiation, one can better understand its applications, risks and benefits.

The Nuclear Concepts and Technological Issues Institute was designed to prepare secondary science educators to teach the basics of nuclear science, radiation and applications. The program is offered through the Nuclear Engineering Department, College of Engineering, as a special topics course (NUCE 497B) and is held at the University Park campus of Penn State University. Participants receive six graduate credits upon completion of the program, but more importantly, they have the opportunity to learn both inside and outside the classroom.

PROGRAM DEVELOPMENT AND ORGANIZATION

The first Nuclear Concepts program was conducted during the summer of 1970. Initially the program was developed by the Penn State Nuclear Engineering Department with the Pennsylvania Department of Education. The program was expanded in 1974 to include teachers from other states. The program has evolved through 17 years of experience, evaluations and suggestions from teachers attending the institute. Over 525 teachers have successfully completed the Nuclear Concepts Institute since its introduction in 1970.

NC&TII

The program was organized by the faculty and staff of the Nuclear Engineering Department and facilitated by the Continuing Education Staff of the Keller Conference Center. Dr. Anthony J. Baratta was the Project Director and Faculty Advisor for the 1987 Nuclear Concepts and Technological Issues Institute. Candace Rusnak, Technology Education Specialist was the Program Coordinator and Laboratory Instructor. Mr. William Curley was the Continuing Education Conference Center Coordinator.

The 1987 Nuclear Concepts program was based on the successful elements of previous programs and further developed with the ideas and suggestions from past participants. This feedback was responsible for the increased focus on technological issues. This continuing evaluation process allows adaptation to the constantly changing energy and educational environment and ensures that the program remains current and useful fo [illegible] participants.

PROGRAM OVERVIEW

Information about the 1987 program was distributed by program sponsors and by Penn State through newsletters, publications and direct mailings to secondary schools. The four week long program includes an intensive background in the basics of nuclear science, laboratory experiences, field trips and discussions. The first two weeks provide instruction in radiation and atomic physics fundamentals upon which more complex issues can be intelligently discussed.

Participants received instruction in the basics of nuclear science, including nuclear models, radioactive decay laws, interaction of radiation with matter and nuclear reactions. In addition, the teachers were given an introduction to health physics and radionuclear applications. The basic principles of nuclear reactors and reactor theory, fission and fusion were also covered.

Topics of interest were requested from participants before the institute so that guest speakers with the appropriate background knowledge and expertise could be contacted. The discussion and current topic sessions included energy overview, radon gas, mutation breeding, low and high level radioactive waste, epidemiology, decommissioning, West Valley Demonstration Project , and the TMI-2 recovery program. Discussion sessions were more interactive this year and included a "mock" public hearing.

Laboratory experience continues to be an important part of the program as the teachers were able to have the opportunity to work with radioactive materials and were able to participate in neutron radiography and neutron activation analysis demonstrations. Ten laboratory sessions were conducted over the four week period. Most of the laboratories could easily be adapted to a secondary science curriculum. A listing of laboratory experiments and objectives is provided in the Appendix.

The American Nuclear Society's Display entitled "The Atom in Everyday Life" was available during the last week of the program. The U.S. Department of Energy's display entitled "Managing the Nation's Nuclear Waste" was also available during the institute.

There were two field trips this year. One to a plant which uses radiation in the processing of materials and a trip to Three Mile Island Nuclear Generating Station. The first trip was to the Perma-Grain wood-plastic processing plant. In this facility, gamma radiation from Cobalt-60 sources is used to polymerize plastic which is impregnated into wood. This wood product is more durable and is used for flooring in high traffic areas such as shopping malls, hospitals, airports and other facilities. The tour of the plant demonstrated the manufacturing of the product from start to finish.

The trip to the Three Mile Island Generating Station provided an opportunity to see an operating plant (Unit-1) and also the recovery efforts at Unit-2. The tour guides were very knowledgeable in the operations of nuclear plants. A package of slides and written description of each slide was provided to each teacher for use in their classroom. The slides were very useful in showing the major components of a nuclear power generating system.

Participants were asked to complete a project based on a related topic or issue. These projects could have been a lesson plan, unit or other type of project which would be useful in the classroom.

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PROGRAM IMPACT & EVALUATION

Although a large amount of information is presented in the program and much work is required in classroom preparation, testing and laboratory write-ups, the Institute continues to receive positive evaluations. A large majority of the participants claimed the program was worthwhile and provided them with material to take back to the classroom. One of the participants commented that the program was the best and most comprehensive of any of the science institutes that he had attended. The program is also claimed by the participants as one which is needed to fill the gap in nuclear science education at the secondary science level. This claim is further reinforced by the evaluation of curriculum materials* by the American Nuclear Science Teachers Association. (*Nuclear Science Education Materials: American Nuclear Science Teachers Association - Educational Materials Research and Evaluation Committee Report). A 1985 graduate of the Nuclear Concepts program commented that the program provided a lot of quality information and that he is still using the Nuclear Concepts materials in his classroom.

Graduates of the Nuclear Concepts program organized their own professional organization in 1974 calling it the Pennsylvania Nuclear Science Teachers Association. The name was later changed to the American Nuclear Science Teachers Association (ANSTA) and become affiliated with the National Science Teachers Association and the American Nuclear Society.

The teachers are invited to bring their students to Penn State's Breazeale Nuclear Reactor for a day of experiments and instruction. The possibility of student projects with irradiated seeds, fruit flies and other items is also discussed along with the availability of the Cobalt-60 facility. Most of the items to be irradiated are shipped to the Cobalt-60 facility, irradiated and shipped back.

The participants are also invited back to attend in-service programs, some of which are held in conjunciton with the ANSTA annual conference. At this time, many of the participants provide feedback to exchange ideas with the Nuclear Concepts staff and other nuclear science teachers. Currently the ANSTA annucal conference is held during the first weekend in May. The 1987 program was held in Baltimore, Maryland and the 1988 program is being scheduled near Cleveland, Ohio.

Many graduates of the Institute have assisted utilities in various public education efforts. They may also be called upon within the local community to conduct formal and informal education programs for teenagers and adults. Teachers may also be called upon within the local educational community for inservice programs.

CONCLUSION AND RECOMMENDATIONS

The 1987 Nuclear Concepts program was more interactive than many other programs in the past. This was due to the interest and participation of the teachers and also of the presenters. The focus on issues seemed to draw more participation and this type of interaction should be further developed in future institutes. The laboratory program received good ratings, however more can be done to provide ease of use in the classroom. For those schools who do not have the necessary laboratory equipment, alternative methods of teaching such as computer simulation need to be included and further developed. There were quite a number of cancellations by potential participants to the 1987 program. In order to try to reduce that cancellation rate in the future, a deposit will be required of all accepted applicants, this deposit will be returned upon particpation in the program. The Nuclear Concepts program continues to be rated by the educators that participate as a useful eductional program that provides a unique opportunity for information and hands-on experience..

Laboratory Experiments, Demonstrations and Objectives

1. Familiarization with the Characteristics of Geiger-Muller Counting Equipment
   - A. To determine the characteristics of a G-M counter
   - B. To determine the slope of the Plateau and the operating voltage for the G-M counter
   - C. To determine the resolving time of the G-M counter
   - D. To prepare a card-mounted radioactive standard
   - E. To determine the efficiency of the G-M counter for 2.29 Mev Beta particles

2. Radiation Counting Statistics
   - A. Statistical Nature of Radioactive Decay
   - B. Statistical Nature of sample preparation and positioning

3. Radiation Measurement Variables
   - A. Counting Geometry Factors
   - B. Radiation Scattering Factors

4. Radiation Measurement Principles
   - A. Depth Gauging
   - B. Density Gauging

5. Determination of Half-life
   Cesium 137 and Barium 137m Isotope Generator
   - A. To determine the Half-life of Barium 137m
   - B. To observe Secular Equilibrium of the system

6. Interaction of Radiation with Matter
   - A. To study the interaction of alpha radiation with matter
   - B. To study the interaction of beta radiation with matter
   - C. To study the interaction of gamma radiation with matter

7. Radioisotope Handling
   - A. To practice the use of survey meters for dose rate measurements
   - B. To calculate the activitey of a sample by means of an exposure rate measurement
   - C. To perform contamination surveys and practice decontamination.

8. Biological Tracer and Autoradiography
   - A. To study the rate at which phosphorus-32 is absorbed by plant roots and translocated to the leaves
   - B. To deomonstrate the techniques of autoradiography

9. Activation Analysis Using a Neutron Howitzer
   - A. To demonstrate the use of a neutron howitzer
   - B. To Demonstrate the concept of neutron activation
   - C. To study the production and subsequent decay of Indium -116m and the complex activation and decay of Silver-108 and Silver-110.

10. Approach to Critical Experiment
   - A. To study the operation of a nuclear reacotr
   - B. To study the concepts of neutron multiplication and critical mass.
   - C. To participate in bringing a reactor to critical conditions

11. Gamma Ray Spectroscopy
   - A. Familiarization with single channel analyzer equipment
   - B. Using known gamma ray emitters, produce a calibration curve
   - C. Determine the identity of unknown gamma ray emitters

12. Neutron Activation Analysis
   - A. To understand the technique of Neutron Activation and subsequent analysis
   - B. To determine qualitatively and/or quantitatively an unkown

13. Neutron Radiography
   - A. To demonstrate the concept of neutron radiography
   - B. To participate in a neutron radiography experiment

NUCLEAR EDUCATION OF TEACHERS IN HUNGARY

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The New Curriculum

In the 1970-es the high-tech revolution and the demand for a corresponding school-curriculum reached Hungary. Like in the U.S.S.R., also in Hungary the Academy of Sciences took the initiatives and recommended the outlines of a new science curriculum for schools. Based upon this framework, the new school curriculum became an official one and in the 1980-es it began to be realized in the Hungarian schools. The main guidelines were *more student activities, conscious use of differring models of reality, more emphasis on motivation and relevance, more attention devoted to those modern chapters of physics which were about reshaping the technological and social environment.* The teachers were not fully prepared for such strong changes of emphasis, there was some reluctance, but the students welcomed the fresh approach: "*For a newborn baby everything is new.*" Finally the majority of schools decided to use the modern schoolbooks instead of those with a more traditional realization of the state curriculum.

Nuclear Curriculum

In the grammar schools (taking about 20% of youth the population) beside *statistical physics* (entropy as disorder) and *standing wave model of the electron* (bond structure of solids) the *nuclear physics* was a chapter which has obtained higher attention. After the oil crisis the public and political attention focused to the energy issues, this aspect was chosen as the main line to design the nuclear chapter of physics (about 14 lessons in grade 12, compulsory for every grammar school student, even for humanistic oriented ones) By omitting the romantic story of the discover of radioactivity and the grandeur of accelerators, school nuclear physics begins with *the discovery of the neutron.* By using the simple concepts of momentum, force, scattering *the liquid drop model of the nucleus* is reached in a direct straightforward way: the nuclei are aggretes of constant density, and the interaction among nuclear particles have a short range compared to the size of the droplet. The behaviour of liquids was studied experimentally in details in earlier grades, thus the droplet model leads to the *binding energy of nuclei* in a logically very simple way. Beside the volume (heat of boiling) and surface (capillarity) terms one has to take into account the Coulomb term (energy of a charged sphere) and the Pauli term (the number of protons and neutrons try to level up). Simple indeed. Now radioactivity is introduced as *the nuclear way of cooling down* (beta decay: neutron-proton levelling, alpha decay: disintegration of overcharged droplets). Just to get a feeling of reality, the prices of the different chemical elements (isotopes) are discussed a bit from the point of view of energy stability (iron becoming the cheapest metal). The radioactivity (its penetration, half life, statistical nature) is demonstrated in a large fraction of the grammar schools by *Geiger-counters* (preferably interfaced to personal computers, to get nice decay curves). The radioactive source (ROTOP, made in GDR) is a solid sample of ^{137}Cs from which ^{137} Ba*

can be washed out. (Authorized for school use.) The solution demonstrates the 2.5 min gamma half life nicely in the class room.

Having the droplet model of the nucleus in hand, it is easy to introduce the *fission*, the neutron-richness of fission fragments, the possibility of nuclear chain reaction, and the unavoidable radioactivity of fission products. Both *nuclear power station* and *radiation protection* come up as natural issues, what the young people find understandable, relevant and interesting. There is a general feeling that nuclear physics is simpler than e.g. alternating currents. So far so good.

Teaching nuclear physics happens in the early spring in grade 12. The students measure the class room background, then they are able to watch the exponencial decay of the ^{137}Ba* sample. A few days later, in late April-early May of 1986 the tv announced the Chernobyl accident (next door to Hungary), and the grammar school students got excited: let us use our knowledge! Measuring the background activity in the class room and outdoors, the activity of shoe sole, soil, leaves, lettuce became a natural bahaviour (like scale or Ohm's law was beforehand). *Becquerel* and *millisievert* turned out to be not only abstract school stuff but very real things. And the physics teacher became an authority in the chaos of disinformation, in the emotional media manipulation. For this interest, the physics teachers became thankful (if not to the Chernobyl catastrophe but) to the new nuclear curriculum.

As a fallout of Chernobyl, the public in Hungary became sensitive to the nuclear issues (safety of nuclear power, deposit of radioactive waste, reexport of spent nuclear fuel). Hungary is a country poor in energy sources. Our brown coal contains a lot of sulphur, menacing with acid rain. In the small and flat country hydroelectric power station is very controversial from environmental point of view; carbohydrogens depend on Soviet supply. Having a modest uranium deposit, nuclear power has become a relevant component of Hungarian electricity production. In 1988 e.g., 46% of the electricity made in Hungary came from the Paks Nuclear Power Station (what the conference participants had a chance to visit). In this state of affairs, the interest in and the responsibility of nuclear education is increasing.

Teacher Training

Due to the traditionalism of university education, most of the active Hungarian school teachers learned just a bit about the nucleus in very historical, descriptive approach, far from the educational maturation of mechanics or electricity. For them, teaching nuclear physics was a new possibility, new duty what they were not prepared for. Fortunately, history helped (nuclear disarmament issue, Chernobyl, Paks, nuclear waste disposal). The teachers started learning.

The Department of Atomic Physics at the Eötvös University launched intensive (methodology, lab, computer supplemented) training for volunteering groups of teachers (120 hours per course, terminating in a state-controlled ground-level exam in radiation protection). Just now the fourth course runs, but in means only 100 physics teachers in a country of 10 million people. But from these "nuclear teachers" a country-wide network was created not only for in-service training of secondary school teachers, but for the dissemination of actual information as well. (Intended location of radioactive waste deposits, CO_2 green house situation, cold fusion controversy, international agreements and manifests about SO_2, NO_x, CO_2, nuclear release, its future limitations, software for power and environmental and risk education.) In at least of half of the counties this network is alive, organizes seminars, nuclear plant visits etc. (You had a chance to meet some of these networked teachers at the conference. They served as workshop assistants.)

The teacher networking culminated in 1988 in a seminar at the Paks Nuclear Plant. The teachers devoted their long fall weekend, they have got first-hand (scientific. economic, factual and hard) information about the "hot" issues. During this meeting, further school networks originated (radon-monitoring network, acid-rain-monitoring network, see Volume II). The main educational goal is, to make nuclear knowledge realistic, empirical, logical, relevant, understandable for teachers (as Newtonian dynamics or direct current are). The hope is that a chain reaction develops: from the expert to the nuclear teacher network, from them to other physics teachers, then to the young people, and further on, may be, to the parents.

Outcome

There are personal indications, that the nuclear physics is becoming (has become) a well established part of the grammar school (academic highschool) curriculum, which is meant also for humanistic oriented students. Even the "young poets" consider this part more relevant and interesting than some other chapters of compulsory physics (e.g. Kirchhoff law or law or lenses). It is certainly the most popular modern physics chapter, which is able to fight for survival with the classical chapters of physics. We hope that once upon a time it will penetrate also the university entrance exams (organized not by schools but by universities). But this is "emotional" evaluation, based on stories told by enthusiastic teachers.

The respect of the modernized curriculum was strengthened by the *fact* that the Hungarian students improved considerably in the *International Assessment of Science Achievements* for all the three age groups (10, 14, 18). (First IEA science assessment: 1970. Second IEA science assessment: 1983. Replay of the second assessment for Hungarian grammar schools: 1989.)

The Institute for Experimental Physics at the József Attila University in Szeged organized a country-wide reassessment of science achievements for the Hungarian grammar schools, to learn the impact of the new grammar school science curriculum and that of the alternative school books in 1989. The 40 schools were selected to be statistically significant from the point of view of sociographical (city, town, village) and niveau (good/weak university enrollment). Consequently the 1120 students of the grade 12 (age 18) represented well the Hungarian academic school-leaving youth population. The majority (58%) of them does not intend scientific-technical-medical carrier. This assessment confirmed (by using the IEA-questionnaire) that the science achievement improved since 1970, in spite of the new content what teachers were originally unprepared to. (The improvement was a modest 3% for non-science-carrier oriented, a strong 16% for science-carrier oriented students, related to the 1970 results.)

As a by-product, we have learned, that in the homes of 25% of children computer is available. 81% of them does not use, 17% uses it less than one hour per day, 2% uses thee computers in average more than one hour per day. 22% of the students has seen computer demonstration by the teacher, 3.5% used computer him(her)self in the school.

A modest result.

The main question what we try to answer now in Hungary, by using the possibilities of the grammar school science subjects (offered to everyone intending academic carrier): *can we educate the incoming educated generatio [illegible] rational benefit/harm assessment of energy alternatives, to logical risk assessment and to individual decision making?* This is just the central issue of the present conference.

The last question we asked the 1120 high-school-leavers was: "*If you could decide, how would you solve the increasing power-demand of the people in Hungary in the coming decade?* (Assume that the demand of industry does not grow.)" The answers differred a lot from the opinion of the media people! The students answered:

by fossile (coal) power	5.1%
by water power	20.7%
by nuclear power	58.8%
restricting the public use	2.7%
buying electricity abroad	8.6%

(70% of those intending scientific carrier opted for nuclear power. 56% of those intending non-scientific carrier opted for nuclear power.)

DISCUSSING NUCLEAR POWER

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The DIS (Discussion of Issues in School Science) project was set up in 1988 and funded by the ESRC as part of a number of linked research projects on the general theme of The Public Understanding of Science. The project focuses on 17 year old students studying a course on Science Technology and Society in nine different schools.

The uses of power in general, and of nuclear power in particular, are topics in this syllabus (GCSE NEA) and its examination includes a requirement for the assessment of each candidate's contribution to small group discussion. This research therefore fitted very easily into the school work. The students were prompted by the watching a video on nuclear power in their schools; at its conclusion they formed friendship groups of three or four and sat down to discuss the subject among themselves, tape-recording their talk as they did so. This article is the first report on their discussions on nuclear power.

PREVIOUS RESEARCH AND EVALUATION STUDIES

One approach to studying students' views on nuclear power and other related considerations is simply to assess what relevant physics they know. A recent questionnaire study (Conforto et al 1989) of Italian school and college students did just this. In the aftermath of the Chernobyl disaster the authors set questions on various aspects of radiation and reported that the knowledge displayed was "quite poor", that answers given after the Chernobyl incident had not produced more precise information, and that there was a negligible difference between the knowledge of school and college students.

In an earlier study of 15 year old students (Solomon 1985) an attempt was made to identify the common elements of informal knowledge about power and energy which students brought to the study. It was shown that school physics knowledge was little used and, indeed that it was often not appropriate for the social context. The pupils did possess quite a considerable amount of knowledge about alternative resources, although not about the problems of harnessing them for use.

Research on students' attitudes towards nuclear power can follow one of several different tracks. Questionnaire studies of students' attitude(e.g. Fife-Schaw et al) may draw out differences related to gender or to the school subjects studied. Others, such as Eijkelhof (1985), have studied change in attitude by administering questionnaires before and after a school course on nuclear energy. One of the most interesting findings of this work was that statements about nuclear power (a high profile issue for Dutch students) showed less movement as a result of school work than did ones about preserving food by irradiation. The author commented:*It may be that the contents of the unit have a greater influence on students' opinions on topics which are not the subject of recent public debate.* Such results raise questions of two sorts.

How early do such attitudes on public issues form?

How best may issues with high saliency be addressed in school?

Some answers to the first of these question may be given by research into Environmental Education in the USA. According to a review paper by Specca and Iozzi (1984) attitudes on many "green" issues begin to form as early as nine years of age, are relatively stable by thirteen, and the knowledge used to defend them comes mostly from parents, friends, and television.

This suggests that the consideration of nuclear power, which certainly fits into the general category of a "controversial issue", may well encounter a variety of pre-formed opinions among secondary school students. It will also be controversial in so far as it involves value judgements. Since the introduction of the Humanities Curriculum Project (Stenhouse 1983), and even before that, the teaching of controversial issues has been justified both for its moral content and for the validity of its representation of a field of study (Dearsden 1982). Translated into the context of physics education this would imply that we need to encourage discussions of nuclear power both because it allows reflection on social and ethical positions, and also because its presence in a physics program would counter the widespread impression that physics is only concerned with doing mathematical problems, or with carrying out practical work which is at a long remove from human concerns and values.

Physics knowledge about nuclear power is important but the results of Eijkelhof and Solomon, quoted above, support a commonsense view that where opinions are already formed there may be some resistance to didactic teaching. Active participation in learning, under such conditions, might be more readily engendered by small group discussion work. It has been argued by Bridges (in Wellington 1986) that this is the best way to allow students to voice their own value positions, and to appreciate the positions of others.

AVAILABLE KNOWLEDGE

The video on nuclear power was edited from a long program made soon after the Chernobyl disaster. It began with some instruction about the operation of a conventional AGR station. After this there were accounts of the French, Swedish, and American policies on nuclear power. The Three Mile Island incident, and the Sizewell B inquiry, were also discussed. In the final moments of this 20 minute video there was a confrontation between Lord Marshall (Chairman of the CEGB) and Jonathan Porritt (Friends of the Earth) with contribution from an American risk assessor. The excerpt finished quite abruptly on a note of disagreement between Marshall and Porritt.

There were no signs that the contents of the video were not understood, but it was also clear that a filtering process went on inside the students' heads. In educations we are used to the constructivist approach to learning which insists that students are not empty of knowledge when they come into our classrooms, and that they process the information they receive, often using analogies or their existing mental models which they may "fine tune" to make them fit better with the perceptions or information being received. In the case of the DISS discussions we needed to explore what other knowledge the students possessed, and also what factors influenced how they interpreted the information from the video.

Chief amongst the items of extra relevant knowledge used was a quite impressive display of information about renewable energy technologies, ranging from hydroelectric and wind power to aquifers and tidal barrages. The students also commonly spoke about the disposal of nuclear wastes, acid rain, the depletion of fossil fuel stocks, and the decommissioning of nuclear power stations, none of which was in the video. In several discussions nuclear weapons were mentioned but this was almost always immediately challenged by another student in the group making a clear distinction between power for civil and military uses.

To present either the information obtained from the video, or the students' existing knowledge, as though it could be listed item by item in a neutral fashion would be a travesty of the real nature of these discussions. The video itself emphasized the different approaches of France and Sweden to nuclear power. The final confrontation made clearer still the different possible interpretations of data by groups within this country. This probably had some effect on the discussion strategies that the students used and on their reception of the knowledge.

It was common to find quite over-statements about the bias in statements of the government or the CEGB who wanted to "keep things quit". Conversely there were students who were unwilling to trust the Friends of the Earth on the grounds that they had just "got to be in the News". This recognition of bias may be the result of an existing mental representation of the knowledge giver. In two cases this produced immediate prejudicial comments - "that fat guy, fat guy!". A feeling that the knowledge had been manipulated in some way produced at least two pronounced effects on the reception of this information. In the first place it led to a lack of trust - "they would say that" - and a consequent denigration of the information. But a more general perception of bias can have a sadly alienating effect of powerlessness. Comments like "no one tells the public anything", and "we cannot tell", were often disincentives to any further consideration of the issue.

USES OF KNOWLEDGE

The students were given no discussion "task" by their teachers but most groups took the opportunity to discuss the pro's and con's of nuclear power in a simple risk/benefit approach to the question. To this end they not only brought in their various items of knowledge but also tried to weight up nuclear power either against fossil fuels or as an alternative resources. The factors they most commonly considered were

comparative safety,
pollution,
cost, and
employment,

with the first of these being far more frequent than the other two. Fuel conservation was not mentioned as an option.

The video had produced some numerical risk forecasts which the students often reiterated with wonder. A 45% chance of an accident similar to those at Chernobyl or Three Mile Island happening in the next 20 years, as given by an American risk assessor, was clearly memorable, easy to understand, and worrying. By contrast figures given by the CEGB about the Sizewell B reactor having only a 1 in 10 million chance of an accident seemed almost mythical and unimaginable. What was easier to understand was human error and its inevitability. "Nothing", they said as if it were an axiom, "is ever completely safe".

In general it seemed that few took the risks as threats to their own lives ("I shall be old or dead by then!"). On the other hand the well-known NIMBY (Not In My Back Yard) effect also surfaced. Whether or not they could visualize their own lives or health being at risk they certainly did not want a nuclear power station near them!

Economic cost was more difficult to handle. Discussion points raised showed clearly the recent moves in public rhetoric from having urged the comparative cheapness of nuclear power to realizing the huge but uncertain costs of decommissioning power stations. Pollution from radioactive wastes was often contrasted with that from acid rain. But for these young people of 16-17 years of age, the possible effects of energy policy on employment were, predictably, taken quite seriously and could sometimes be off-set against risk. As one male student from a high unemployment region in the north east of Britain remarked during a discussion on risk "Yes, I would work at a nuclear plant – if the pay was good enough."

This sort of classroom discussion is often called "decision-making" as though the whole point of such activity was to reach a consensus on the best national strategy. In a complex policy issue such an objective does seem more than a little unrealistic. Some groups did ask each other what they thought should be done but this was more often answered as if it were a "for or against?" debating move. Just occasionally some strategy was suggested – that there should be small power stations in remote sites, that more research should be done, that the wastes should be fired out into space, or that alternative energy research should be better funded. On the whole the results of discussion, if judged by such a simplistic national decision-making criterion, were not impressive.

MOVES WITHIN THE DISCUSSION

There were three general categories of talk. One of these we described as "framing" since its purpose seemed to more designed to "get inside" a particular frame or set of images than to communicate ideas. Often they just rehearsed what they had seen on the video or spoke about their own experiences in little more than a story-telling mode.

That kind of talk merged almost inperceptably into a kind of "deliberation" where actively putting ideas across to each other. The purpose of this seemed both to make explicit their own positions, fears, and values, and to elicit the reaction of others to them. They exchanged views on the French strategy of providing neighbourhood inducements for installing a nuclear reactor, or on the Swedish attempt to supplement their fuel resources by growing willow sampling. They would personalize the issues by considering what their own reactions might be to seeing a nuclear reactor instead of a farm outside their window, or they would ask their friends if they would be willing to work in the nuclear industry. And where they had private fears or phobias this was the place where they expressed them through prejudicial comments ("the Danes think the Swedes are stupid!") or jokes (about living by candlelight). The students seemed to be negotiating with each other what sort of notions and experiences were relevant to the issue of nuclear power.

In the third and more committed phase of the discussions the students challenged each other to say where they stood on the nuclear/non-nuclear device. We called this stage "Which side of the fence?". It seemed to be a strategy drawn from public debate, and indeed the students often counted up how many there were "for", "against", and "not decided" in true committee fashion. What surprised us most was that this phase, which would seem to be the culmination of argument and deliberation, often took place at the very beginning of the discussion. We guessed that the purpose of this was to enlist sufficient support to make it possible to talk more freely. Finding oneself in a minority of one in a group of otherwise committed students would probably not be conductive to exploratory talk.

EDUCATIONAL REFLECTIONS

In the last ten years many enthusiastic physics teacher have been trying to introduce more "relevant" material into their lessons. This issue, of power supply, may well have headed the list of topics covered. Many methods were tried. Some taught about fission and the construction of nuclear power stations; some gave out lists of arguments for and again nuclear power and asked for essays. In the first five years the most popular method was a "simulation" in which students were given roles to play and definitive information to use. In more subtle variations of this gaming approach slightly different date were given to opposing groups.

But when the fun was over a few voices could be heard asking what value system the students might use if they were free do discuss the risks and benefits to different sections of their society and had not been assigned to particular roles. That was a hard question to answer if the students had been given parts of play and "hard facts" to use without question.

So, in the manner of either a "neutral chairman" or a "balanced chairperson" (who was prepared to play devil's advocate if only one side of the argument had surfaced) some teachers then tried to promote whole class discussion of energy themes. No one knows better than I the difficulties of getting this going on a cold Monday morning, or its equivalent. Even if discussion does take off, how often can we get the quiet and the shy to participate?

What has been striking about the students' discussions that we have so laboriously transcribed over the last year, is that they worked. Almost without exception the groups of three of four talked together honestly and seriously, despite the presence of the tape-recorder. They shared their knowledge, their feelings, their personal values, and their sense of social responsibility. Even the teachers were sometimes surprised at the quality and fluency of their talk.

Not many of these pupils were taking physics at Advanced Level with the intention of making it their career. That was simply an artifact of the school time-table. The few who did have such aspirations seemed to enjoy the course, and participated well. We fled that such discussion of social issues would form a valuable part of the preparation of a future physicist who might possibly find employment in the nuclear industry. For the majority of our students, however, school physics had proved difficult and they were not contemplating any future qualifications in the subject. For them the course was one in "citizen science" where they could use understanding of people and their predicaments as well as relevant content from physics. Using values in addition to knowledge is, as Wellington (1986) suggested, an essential part of teaching about nuclear power; it also a hallmark of the public understanding of science issues.

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GOIANIA
(SUBSTUDIES FOR A TEACHING MODULE)

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THE STUDY

Attitudes regarding science related issues are often shaped by information obtained at home, from mass media or other incidental sources. The habit to take this information for granted is well stablished and makes it the more problematic, since the acceptance of this knowledge shapes the judgement and the behaviour of people in potentially dangerous situations. For the technologically based society of present times the search for a better understanding of science becomes a matter of welfare and safety for the population involved. We want to present the thesis that it is a fact that most of the information the groups involved in this study had about radioactivity, at the time of the Goiania Incident, was obtained from sources other than School Learnt Science (2b),(7). Furthermore, the lack of confidence Brazilian students have about school as the source of a useful kind of knowledge seems to be partially responsible for the lack of interest in seeking further scientific information.

The subject of radioactivity is not really worked in school, or even at the University level,from the point of view of its social and technological implications. High school students do not have educated means to acquire science based informed approaches.

We propose that modules related to "Science-Technology-Society" issues. STS, be introduced as regular class activities in current courses, without disruption of what is today called the "official curriculum". The main objective of these modules being to give the students a chance to develop fundamented judgement based on scientific grounds making use of reliable sources to procure information. Among such modules the one related to the understanding of "Radioactivity and its consequences for Society: risks and benefits" should have priority, because of the large number of issues that the common citizen encounters in today's society requiring sound reflection and judgement: nuclear power stations; the proliferation of nuclear arsenals; uses of radioisotopes for health,agricultural and food control; industrial applications, etc. It is important to clarify that the learning of these basic facts does not mean a formal introduction in the subject specifically (as a physicist should have), and yet, it should cover the necessary information to permit the individual to handle potentially dangerous situations. The choice of STS topics relevant for each group of subjects may depend on regional specificities. Nevertheless it is possible to reach concensus about some subjects which have universal importance, such us " Energy, production, uses and conservation" and "Radioactivity, natural, artificial and its consequences for life and environment".

The present pilot study uses essentially a qualitative approach. Interviews with groups of students: primary, secondary and university, secondary teachers of physics and people dealing with other areas than science and technology, which will be labelled "others", constitute one of the sources of data for this study. All subjects had at least 8 years of formal education. A questionnaire was used in order to organize and control the discussions about the "Goiania Accident" and how the subjects viewed their knowledge about radioactivity. The answers to some of the questions were statistically collected, each subject within the group stating clearly his/her choice. The groups interviewed were constituded by five to nine individuals, all belonging to a same category, totalling fourty people.

Another set of data was obtained from newspaper accounts of the accident published within a month of its discovery. The data thus obtained subsidized the preparation of class activities related to STS modules on the subject.

I) The questionnaire seeks to obtain information about how the subjects recall the Goiania Accident almost two years after and how much and where was obtained the knowledge about radiactivity they possessed before the accident. Another aspect that we wanted to know of was how the crisis and fear that overcame the country, so vastly advertized through the media, motivated curiosity or the need for further understanding and knowledge about the subject.

a) INTERVIEWS: QUESTIONNAIRE AND DATA

1) WHAT ARE THE WORDS THAT COME TO YOUR MIND WHEN WE TALK ABOUT RADIOACTIVITY?

The answers can be grouped in two sets:

a) Primary teachers and students and others are clearly not influenced by schooling, their vocabulary reflects their daily experience : x-rays, radiation and harmful are the most frequent words.

b) Secondary teachers and students and freshmen students have a scholarized vocabulary: atomic nuclei, emission of particles, alpha, beta, gamma radiation, contamination and ionization are words of easy recall.

2) HAVE YOU HEARD ABOUT THE "GOIANIA ACCIDENT"? HOW MUCH CAN YOU TELL ABOUT IT?

But for one subject all admitted having heard about the accident mostly via TV: 80%.

PRIMARY SCHOOL STUDENTS had the poorest recall, practically could not describe the "accident" and were mostly impressed by the harm caused to people and the novelty of the situation. The best answer "...accident in 87 that affected many people and some died because of the radiactivity of a small object... that was handled by others in such a way causing them harm"

PRIMARY SCHOOL TEACHERS describe the accident as Cs 137 contained in a medical equipment; some associate cesium to X-rays and talk about the harm done to people because it was rubbed on the body and handled, causing death to some people as well as ... "creating fear in other states against the population of Goiania" and ..."creating panic throughout the country..."

SECONDARY STUDENTS make very factual statements about two junk dealers having removed the capsule containing radioactive material or Cesium that was scatttered and ..."poisoned some people and some of them died..". They refer also to the lack of information of people who handled the capsule, attributing to it the gravity of the accident that ..."awakened humanity to the possibility of this type of accident..."

SECONDARY TEACHERS AND UNIVERSITY STUDENTS AND OTHERS describe the facts giving correct details of the location of the medical apparatus, violation of the Pb shield ..."to be sold by poor people...", the ..."handling by many people of the contents of a blue powder contained in a capsule, (cesium), contaminating many places and human beings with radioactivity...". Only one subject talks about "radioactive waste that will take many years to become totally desactivated" and finds it a happy coincidence that the water system was not contaminated. Three individuals talked about "X-rays apparatus" beeing removed and opened causing contamination to people.

3) WAS THE "GOIANIA ACCIDENT"RELATED IN ANY WAY TO RADIOACTIVITY?

Definitively yes, for 95% of the subjects of all groups.

4) DO YOU THINK THAT WHATEVER YOU KNEW ABOUT RADIOACTIVITY WAS USEFUL TO HELP YOU UNDERSTAND THE GOIANIA ACCIDENT?

Yes: 20%; somehow: 30%; no: 50%

5) DID YOU SEEK INFORMATION ABOUT RADIOACTIVITY AT THE TIME OF THE ACCIDENT? WHERE? WHY?

Yes: 30%; no: 70%. There are several sources of information that share preference: school, books, newspapers are equally selected followed by teacher, parents, friends, TV. The reasons given for seeking information are not technical, mostly curiosity because the accident was very well covered by tha mass media at the time of the accident. Most subjects indicated the need to obtain better information about scientific and medical aspects of radioactivity.

6) WHAT ARE YOUR IDEAS ABOUT THE CAUSES OF THE ACCIDENT?

Only one subject attributes the accident to robbery. All others refer to the incident as something very natural, bound to happen because of the social conditions people live in and only one refers to "somekind" of authority that should have been responssible.

7) WHOM DO YOU THINK SHOULD BE RESPONSSIBLE FOR THE ACCIDENT?

Some answers about being the owners of the clinic.

8) HAVE YOU LEARNT THE SUBJECT OF RADIOACTIVITY OR NUCLEAR PHYSICS? WHERE? (some suggestions were made: books, school, media, TV).

books: 15%; school: 25%; newspapers and journals: 10%; 50%: not sure.

9) HOW MUCH DO YOU KNOW OR UNDERSTAND ABOUT RADIOACTIVITY AND RELATED MATTERS? (suggestions: how does it work? what does it do to people and material things?)

Very little discussion. It works like invisible rays that come out of materials.

10) DO YOU HAVE KNOWLEDGE OR EXPLANATIONS FOR THE FOLLOWING SET OF CONCEPTS? (the answer could be yes, no, never heard of)

	yes	no	never heard
i) Atomic structure	50%	30%	20%
ii) Radioactive atoms	50%	25%	25%
iii) Isotopes	30%	30%	40%
iv) Mean life	30%	30%	40%
v) Radiation	80%	20%	0%
vi) Ionization	30%	30%	40%
vii) Contamination	70%	30%	0%
viii) Radiation doses	0%	100%	0%
ix) Biological effects of radiat.	0%	100%	0%
x) Protection from radioactivity and safety procedures	20%	80%	0%

COMMENTS

There are several important facts missing in the data collected during the interviews: (a) the absence of any reference to radioactive waste (11), that was presented as one of the most serious problems in the media, because of the difficulty of solutions and the extent of contamination of houses and city streets (the source was taken from the junk yard to a hospital by bus); objects were stolen from one of the most contaminated houses; soil and plants and domestic animal needed to be removed and even the bodies of the people that died of internal contamination presented difficulties to be buried; (b) there is no mention to the properties of radionuclides in relation to their exponential decay; (c) the concepts of mean life and half life are never mentioned in connection to the dangers of radioactivity; (d) school is not a frequent source of information as seen in the answers to question #5. A study in progress by Nunes et al (7) with a sample of Brazilian secondary students, reaches similar conclusions. The information students possess about nuclear technologies seems to be based on mass media information rather being obtained via the school science curriculum. This information is often badly fundamented and appeals to sensationalism. Aspects of legal responsabilities were seldom discussed along the interviews, in spite of being an issue that interests to all responsible citizens because of the implications for the welfare of populations. In spite of the "accident" having been in the headlights of the media for several months, most of the subjects did not seek further information about radiactivity, for a better understanding of the issues. This seems to be a factor that should enhance the priorities STS modules should be given within the School science curricula.

CONCLUDING REMARKS: APPLICCATION OF STS ACTIVITIES IN OFFICIAL SCHOOL CURRICULA

Science syllabuses, for the vast majority of Brazilian secondary school curricula traditionally organized, cannot longer avoid presentation of topics that affect modern society, as is the case of nuclear technologies. Modern physics has no place in the physics sylabus and some of the "scientific information" comes from the study of atomic structure taught in General Chemistry courses. Very seldom qualitative scientific models are presented to the student. Issues from the point of view of applications are almost never dealt with, unless the student solicits the teacher. If our students are ever going to develop a capacity for decision based in educated guesses we must then educate them for this starting at proper levels early in school life.

As the process of modification of official school curricula is a very slow one, we need to use all available resources at hand to give our students a relevant education that will be carried on to their everyday lifes as responsible citizens, and these should not be only words, that sound nice, and are never practiced.

Public issues, vastly advertised and discussed at the time of the events, such as the Goiania case, motivate the students from different angles: affectively (pity for the victims and fear for their own safety); from the point of view of the economy, as is the case of situations related to energy shortage; other issues will appeal to curiosity and imagination, the Neptun Space flight, and so on.

The introduction of scientific concepts via extracurricular topics, treated by the Physics teacher,in the surroundings of the school and within the official loading time alloted to the discipline, may help achieve the objective of producing a better informed citizen, that should be one of the main objectives of school science. In this manner learning science can become relevant because it deals with attitude change as well as knowlege of basic facts and cognition gain. It is expected that personal conceptions could be modified via confrontation with an "expert's model", bringing about a durable attitudinal change.

The introduction of STS Module activities should emphasize attitude development, making students aware of how science and technology affect our social and economical lifes, and it may be expected that if the learned behaviour is developed at early stages it may be carried through life. We summarize below a set of interative learning approaches to be used in situations where attitudinal change is the main objective (3).

1. Simulations and games.

2. Role play/ discussion/ decision making facts.

3. Cognitive approaches that provide assimilable cognitive imputs.

4. Student led or student group discussion.

5. Use of realistic science related problems affecting society either positive or negatively.

6. Historical case studies, with an analysis of scientists work and lifes, within the context of the era they contributed to science.

APPENDIX

EXAMPLE OF TEACHER MODULE ON RADIOACTIVITY AND RELATED MATTERS (primary and secondary teachers)

GENERAL OBJECTIVES

To develop concepts about radioactivity, its basic properties and applications and its impact in modern society; to bring about an attitude change that can develop from the understanding of a simplified scientific model presented at a qualitative level.

MODEL PROPOSED

* Substances (key words: atomic structure, atoms, nuclei, electron, proton, neutron, element, isotope, source) that have the property to emit espontaneously (key words: radioactive desintegration) invisible nuclear rays (key words: radiation, particles and waves, energy), that interact with matter (key words: radiation damage, defects, ionization, fission, fusion) are called radioactive materials. The radiation spreads out from the source loosing energy and being absorved gradatively while traversing matter, (solid,liquid or gas), becoming less intense with increasing distance (key word: flux) or amount of matter traversed (key words: density, absorption). The action of radiation is distance dependent and caracterized by extensive properties (key words: intensity of source and age) and intensive properties (key words: activity, nuclei composition). Different sources remain in activity for different periods of time (key words: desintegration, decay time). This property explains the origin of nuclear isotopes used for the preparation

of radioactive sources (key words: natural or artificial). Radioactive materials can irradiate (at a distance) or contaminate (direct contact) matter. Radiation might induce radioactivity in matter (new source). Contamination spreads the original source in the environment (matter transport). In both cases neighbouring matter receives radiation and present radiation effects", (8).

It is expected that the cognitive behaviour of the students, developed as the consequence of the conceptual understanding of this model could be useful for decision making attitudes on issues considered relevant for society.

SUGGESTED ACTIVITIES

i) Measurements of background radiation.

ii) Discussion of radiation detectors(personal dosimeters). How do they work, what do they measure, etc?

iii) Models and analogies using audiovisual and computer simulation of atomic models, periodic table, radioisotope production, etc.

iv) Mechanical analogues of Rutheford model:(determination of "nuclear dimensions" by collision probabilities. Experiment suggested in PSNS textbook (8).

v) Analogue model of light nuclei isotope formation using soft and magnetized iron discs proposed by Thomsen (10)

vi) Discussion of risks and benefits of peaceful uses of nuclear energy.

vii) Discussion of nuclear reactors.

viii) Norms and safety procedures, units of measurement and calculations of simplified situations.

ix) Applications and implications of peaceful uses of radioactivity and nuclear energy.

x) Discussion of ionization radiation and its biological effects, a class activity, as suggested by Ganiel (9).

xi) The arms race, nuclear disarmement and the survival of humanity.

xii) Responsabilities: legal and ethical aspects of the use of nuclear energy. Nuclear policy.

A NETWORK OF TOPICS TO DEVELOP AN "EXPERT MODEL" OF RADIOACTIVITY

- ATOMIC STRUCTURE elements
  - ELECTRONS chemical properties of elements
    - CHARGE
      - NEGATIVE e-
      - POSITIVE e+
    - MASS = 1/2000 mass of proton
  - NUCLEUS mass of element
    - PROTONS
      - POSITIVE CHARGE
      - MASS = 10^{-27} kg
    - NEUTRONS
      - NEUTRAL
      - Mn = Mp

- NUCLEI
  - STABLE (infinite life)
  - UNSTABLE (finite life)
    - NATURAL
    - ARTIFICIAL

- RADIATION FROM MATTER
  - ATOMIC EM radiation
    - INFRARED
    - VISIBLE LIGHT
    - ULTRAVIOLET
    - X RAYS
  - NUCLEAR
    - ALPHA (α) PARTICLES (He-4 nuclei)
    - BETA (β) PARTICLES ELECTRONS
      - POSITIVE
      - NEGATIVE
    - GAMMA(γ) RAYS extremely short wavelength radiation
    - NEUTRONS (n) (fission and fusion)
    - NUCLEAR FRAGMENTS (fission)

- EFFECTS OF NUCLEAR EMISSION IN MATTER (energy, activity half time)
  - ATOMIC LEVEL IONIZATION
    - α heavy production of ion pairs- very short range in matter
    - β light production of ion pairs - long range
    - γ high penetrating power
    - n high penetrating power
  - MOLECULAR LEVEL
    - α high molecular dissoc., production of defects in matter
    - β high molecular dissoc.
    - γ low molecular dissoc.
    - n indirect production of dissociation, defects
  - NUCLEAR LEVEL
    - α energy dependent
    - β low nuclear effect
    - γ, n high nuclear effect

- BACKGROUND RADIATION Annual doses in units of milisievert (mSv)
  - COSMIC RADIATION — particles and radiation from outer space 0.30
  - RADIOACTIVE MATTER
    - NATURAL
      - EARTH SOURCES 0.35
      - LIVING ORGANISM 1.35
    - ARTIFICIAL
      - MEDICAL SOURCES 0.40
      - NUCLEAR BOMBS 0.02
      - NUCLEAR POWER 0.001
      - OTHER SOURCES 0.01

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THE PUBLIC ACCEPTANCE OF NUCLEAR POWER IN FRANCE

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INTRODUCTION

It is a great honour for me to participate to this conference on ENERGY ALTERNATIVES.

What I will describe, in my participation to this symposium, is :

1- The context,
2- The information program,
3- The results,

of EDF actions for the public acceptance of nuclear power plants in France.

Obviously, I shall be pleased to answer your questions concerning points which could be missing or not clear.

1. - The economical and political context

1.1 The research of energetic independence

a) The "before nuclear energy" programs

In the fifties and early sixties, electricity generation was based on hydroelectric dams and coal-fired thermal plants. But, in the late sixties because of a relatively high consumption increase, this practise could not be continued as most of hydroelectric sites where already equipped and national coal became rare and expensive.

Therefore, as a result of the overall decrease of national energetic ressources, and because of the cheapness of oil, several oil-fired plants were erected.

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b) The first nuclear steps

Meanwhile, research continued in the nuclear field. Several types of nuclear power plants were built (gaz-cooled reactors, PWR, heavy water reactor, breeder). At the end of the sixties, it was decided to standardise on the PWR type.

c) The nuclear program

In 1973, the price of oil increased so much that it became evident that France could not continue to be dependent for its electricity supply, on foreign sources. Therefore, it was decided to launch a large program of nuclear power plants to recover energetic independence. This program has been and is still considered as vital for the success of France's energetic policy and search of independence.

1.2 Public authorities and political parties

France is a democracy with a centralised government and several political parties.

a) The position of the parties

In order to simplify, it can be said that these parties are divided in a right wing and a left wing, although through time, the limits between right and left can vary slightly.

From the origins of nuclear power until 1974, the year when the current nuclear power program was begun, all French political parties looked on nuclear power very favourably although there was some controversy at the beginning of the 70s when the natural uranium-gas-cooled reactor series was discarded in favour of the pressurized water reactor series.

b) The effects of alternation

When the nuclear power program was accelerated in 1974, the parliamentary opposition in France basically consisted of two leftist parties, the Communists and the Socialists. Their representation was about equal. Faced with a government resolutely in favour of nuclear power, the opposition could have taken the opposing stance and thus won the ecologists' votes. Instead, the Communist Party came down in favour of civilian nuclear power applications. The Socialist Party has always been divided on the nuclear question. This was the case during the 1981 presidential election, the only one where nuclear power was an issue. During this campaign, a large faction of the Socialist Party militated against the nuclear power program and opposed the construction of some plants. After the Socialists came to power, steps were taken to ensure greater participation by local elected representatives in site selection and to provide more information locally. Although the nuclear power program has slowed down since this time, it was not been called into question ; the slowdown is merely a means of matching production capacity to future electricity needs. Unanimity has been the order of the day since. Nuclear energy was not an issue during the recent presdential elections.

c) The ecology movements

Although ecology movements sprang in countries like West Germany and the United States in the mid-60s, they did not appear in France until 1974-1975. They are very disparate in France and have not been abble to form an alliance as is the case in West Germany. Their political base is uncertain, limited to a fraction of the Socialist Party and several smaller parties without much influence. As a result, their showing is very poor during elections. In the first round of the 1988 presidential elections, the ecologist candidate won fewer than 4 % of the votes.

1.3 E.D.F. main actor of the French nuclear program

E.D.F. is a state-owned company created in 1946. It is in charge of designing and constructing all generating plants, operating them, transmitting and distibuting electricity all over France.

With a peak load of 63 000 MW, a total output of 360 TWh in 1987 and a staff of 123 000 people, it is one of the biggest integrated electricity utilities in the world. Its annual turnover is about 136 billion French Francs (24 billion US dollars).

E.D.F. as overall designer, architect-engineer and operator of nuclear plants, is the main actor of the nuclear program.

It coordinates the activities of the components manufacturers such as Framatome for the reactor vessel and Alsthom for the turbine, and the activities of the contractors.

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2. - Information and participation of the public

2.1 The relational context

a) A long nuclear tradition

Since Becquerel and Pierre and Marie Curie, France has a long nuclear tradition which might have helped the development of the nuclear program.

b) The fiscal background

In France, there is no rate advantage for those who live near nuclear plants. This is because those plants are designed and erected with all precautions necessary for creating no nuisance to the neighbourhood. Therefore, it is not necessary to compensate any trouble. But, like any other industrial installation plants are subject to what is called "professional tax". A nuclear plant because it employs many people, has to pay relatively high taxes. Those amounts are distributed among the towns around the nuclear plant. Therefore, it is a factor of financial income, high enough to favor the acceptance of the plant by elected representatives.

On the other hand, closing down plants is a great loss for municipal ressources. This is why EDF's policy is to replace those plants on site, wherever it is technically possible.

c) Participation of local populations to the projets

At all steps of a nuclear plant construction and operation the local populations are fully associated to the project.

- Site selection

In order to gain public acceptance for a site to be open, the elected representatives are associated to the selection as early as possible. All necessary precautions are taken in order to minimize the impact on the environment and to preserve public and private interests. After a public inquiry the site is finally approved by the Prime Minister on the proposal of the State Council.

- "During erection" and "after erection" procedures

During erection works, special procedures are set up in order to facilitate the use of local manpower and help the integration of other staff to the local environment. Schools, sport facilities are created ; roads and communication means are improved.

EDF participate by lending money to the municipalities, which will be paid back later by deduction from the "professional tax".

During 3 years after the construction works are finished, EDF participates in keeping a good level of activity in the neighbourhood by helping municipalities in creating employments.

- During operation

It is a general EDF policy that during operation, the local populations are associated to the life of the plants by providing all services which can be fulfilled by local companies.

2.2 The information actions

a) Upto 1980

From the launching of the program to 1980, the main priority was to open new sites in accordance with the needs. Therefore the main action was to ease the acceptance by elected representatives.

Visites of existing plants in France and even in foreign countries have been organized for municipalities of potential sites.

Also conferences and debates for local people took place. A group of debaters has been trained for this type of activity.
On site, information centers have been erected. The first one was open in 1980.

b) From 1980 to 1985

At the peak of the program, a vast effort of information has been made at both national and local levels.

- national level

A general catalogue of about 300 documents has been established. Those documents were related to energy in general (ressources, French energy policy, techniques...) and to nuclear energy in particular (technique, safety, economy, environmental impacts, ...). The documents were classified in 3 difficulty categories so that the reader can select according to his level.
The catalogue itself was presented in popular newspapers and magazines. People could ask for it and then get all the proposed documents free of charge.
Millions of documents have been thus distributed to all interested people.

- local level

During this period no other action than those listed in the previous paragraph has been undertaken. But these actions have been generalized site per site as they were open. This concerns in particular the opening of information centers for which the strategy was :

. opening of a temporary office as soon as possible,
. opening of a temporary center at the beginning of the works on site,
. opening of the final center when the access roads were completed.

Also, organized tours of plants for the public have been generalized. Those tours are accessible to anybody providing that the booking is made by letter or telephone a little in advance.

c) The present action

At national level, because of the slowing down of the site opening rythme, and after CHERNOBYL accident more specific actions have been undertaken, concerning :

- medical professions : a catalogue of about 20 documents related to the needs of those professions, has been established and sent to those who live in the regions where plants are established.
About 1/4 of the members of those professions in France (25 000 people) received the catalogue and 20 % of them asked for documents.

- teachers :
A catalogue of 27 documents has been prepared for teachers of the 1st cycle of secondary schools. It was sent to 11 500 schools in France. 80 % of them asked for documents.
Teachers and doctors are our favourite targets because they are good relays of information and they are seen by the public as impartial people.
At local level, the action continued as mentionned before but the stress was put on relation with doctors and teachers. Also EDF public relation managers are now the main points of contact with the press and media because they can report directly on the life of the existing plants.

d) The future action

The stress will be put on the continuation of the present action.
There is a thought for extending the action toward the medical professions to the overall country, which represent about 100 000 persons.
Another action will be the preparation of catalogues of documents for the teachers of the 2nd cycle of secondary schools. Three catalogues are going to be prepared for geography, economy and physics. In total, 45 000 teachers shall be contacted.
A third action will be the preparation of a new general catalogue more centered on economical, safety and operational aspects of nuclear plants which are those coming out of our visitors' questions.

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3. - Results

3.1 The success of the French nuclear program

About 15 years of the launching of the French nuclear program, it can be said that it is a success. At the moment, 53 reactors are in service (2 breeders, 4 gas cooled reactors, 1x300 MW PWR's, 34x900 MW PWR's, 12x1300 MW PWR's). 8x1300 MW and 2x1400 MW PWR's are under construction.
They generate about 70 % of French electricity. In 1987, their availability factor was 79 % for 900 MW PWR's and 73 % for 1300 MW PWR's.
The 900 MW PWR's are equipped for load following. In 1987, 2000 load ajustment operations have been performed.

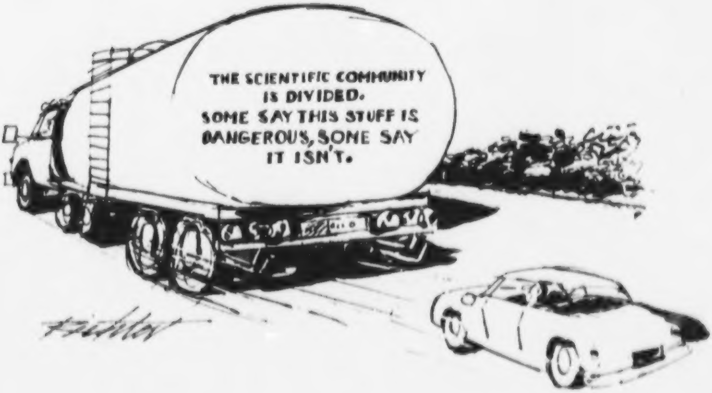
3.2 The success of the information program

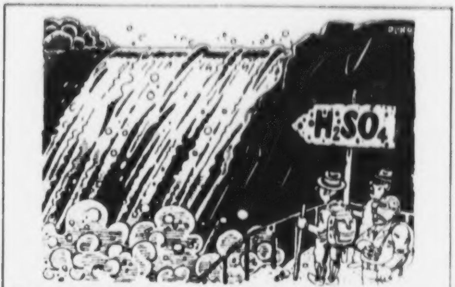
Now that the construction program is well advanced, it can be said that the nuclear program is accepted by the French public. But, it is difficult to detect what has been the impact of EDF's information program in this acceptance. We have the feeling that it is not the only factor of this acceptance but it has been essential to perform it.

Our recommendation could be to undertake information programs well adapted to the local conditions.

EDF is ready to share its experience with other utilities in this field as well as in any other field related to electricity.

RISK EDUCATION


THE SCIENTIFIC COMMUNITY IS DIVIDED. SOME SAY THIS STUFF IS DANGEROUS, SOME SAY IT ISN'T.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WHY IN THE WORLD SHOULD WE TEACH STATISTICS?

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Pick up a daily newspaper and encircle every item in which mathematics is required for its understanding or interpretation. Do you find any equations? Any geometric proofs or trigonometry? Can you find factorizing of trinomials in any of the columns? Instead you will find charts, graphs and words such as 'averages', 'trends', 'projections', 'estimates', 'correlations', 'unlikely', 'chances' and 'improvement'. All these words are in the domain of statistics. The sports pages abound in tables of statistics and charts of team standings, batters' and pitchers' records. Graphs and charts appear on the financial page to show the interest rates and money market fluctuations, and predictors of rates of inflation, changing stock indexes, growths of companies, and volumes of stock traded. No weather report would omit graphs telling us that it is colder, wetter, or windier than last month or last year. And the forecast might be a 40 per cent chance for rain the next day. A look at the advertisements will find statistics being both used and misused. *The Dominion* (1987) wrote 'The fine old tradition of economic charts, breathtakingly simple with big, black lines soaring and diving dramatically in illustration of some economic plight or other, was the linchpin of Sir . . . electioneering in 1975, the year of the national landslide.'

You will also find opinion polls on politicians' ratings, on whether the community should build a new airport or school, on smokers' perceived dangers to their health, etc. Such surveys are now an accepted form of measuring opinion. It is left for the reader to decide whether the results are significant, or the poll was without bias.

Why do we find so many uses of statistics in the newspapers? Many of the decisions we make are based upon incomplete or uncertain data, and statistics can help us choose. Another reason is that many of our choices contain a certain risk of adverse effects. We collectively make decisions about the choice of energy for electricity generation with their respective risks of accidental nuclear discharge and atomic waste disposal, or acid rain from burning coal; of speed limits on highways; of acceptable levels of irradiation of food for preservation; of maximum radiation levels in food, water and work-places; of residuals of pesticides, hormones, fertilizers and chemical additives in foods; of maximum allowable adverse side-effects of medicines, etc. We must be able to balance fear and opportunity by understanding the risk of alternatives. We define risk as the probability of something bad happening, but with no implication about the extent of the badness, that is, of two different events with the same degree of risk the badness of one may be very serious while the consequences of the other may be slight. How are we to react to the following sentence: 'In the United States of America, about 50,000 people die in automobile accidents each year, totalling one million deaths in the twenty-five years of worrying about nuclear reactor accidents.'?

Most people are poor at measuring and distinguishing between large and small risks. Insurance companies who understand risk compare the number of victims who suffer some adversity with the number of people who were also at risk by doing exactly what the victims were doing, but managed to emerge unscathed. Newspapers and radio report on the victim, but not on those who have done the same actions and remain untouched. Urquhart and Heilmann (1984) claims that the lack of acceptance of a uniform standard for expressing risk is one of the reasons that we argue a great deal about certain risk-related issues, and the author advocates a sort of universal Richter scale for risk. We cannot live in perfect security, so we should understand the probabilities in risk well enough to know the relative importance of the dangers. Traditional science courses teach us to think in terms of certainty, which is unwarranted. Educating for risk must be interdisciplinary because, as Dickson (1985, p. 14) states, the sources of risk can be scientific, legal, financial, social, technological, political or any combination. All citizens should learn risk measurement and the balancing of risk and benefit. Thus everyone should be comfortable in the presence of probability and statistics.

This was summed up well by a report to the British Government (Cockcroft, 1982, p. 234) which stated that 'statistics is not just a set of techniques, it is an attitude of mind in approaching data. In particular it acknowledges the fact of uncertainty and variability in data and data collection. It enables people to make decisions in the face of this uncertainty'.

Statistics For All

'More people have to read and understand others' statistics than have to carry out their own statistical research. A first course in statistics should therefore concentrate on statistics as a language.' Thus Haack (1979) described his introductory university course which teaches statistics as a language rather than as a research tool, by emphasizing the interpretation of statistics rather than their calculations. He found that students who had completed a traditional statistics course could understand the statistics they would encounter in the media no better than they had previously. His new course takes examples from the media and treats them in a strictly verbal, non-symbolic manner. Treating statistics as a language is even more important at school level.

After conducting an extensive survey of the opinions from many sectors of society in the United States, the National Council for Teachers of Mathematics (NCTM, 1980, p. 1) made eight major recommendations for school mathematics of the 1980s. In the three which concerned mathematics content and methods, they recommended that:

1. Problem solving be the focus of school mathematics in the 1980s.
2. Basic skills in mathematics be defined to encompass more than computational facility.
3. Mathematics programs take full advantage of the power of calculators and computers at all grade levels. (NCTM, 1980, p. 1).

To organize the mathematics curriculum around problem solving, students must be taught 'methods of gathering, organizing, and interpreting information, drawing and testing inferences from data, and communicating results' (NCTM, 1980, p. 3). They defined basic skills to include 'locating and processing quantitative information; collecting data; organizing and presenting data; interpreting data; drawing inferences and predicting from data' (NCTM, 1980, p. 7). Problems to be solved were to come from everyday situations using real-world data, and from experiments and problems from social science, business, science and technology all sources of messy data. Using calculators and computers, their third recommendation, overcomes this difficulty of doing arithmetic with such data which contain many digits. These recommendations underscore the importance of statistics teaching as part of the mathematics programme.

In the United Kingdom, the Cockcroft Report (Cockroft, 1982, p. 16, para. 776) included statistics in its recommendations for school mathematics.

> Statistics is essentially a practical subject and its study should be based on the collection of data, wherever possible by pupils themselves. It should consider the kinds of data which it is appropriate to collect, the reasons for collecting the data and the problems of doing so, the ways in which the data may legitimately be manipulated and the kinds of inference which may be drawn. Work in subjects such as biological science, geography and economics can therefore contribute to the learning and understanding of statistics. When statistics is taught within secondary mathematics courses too much emphasis is very often

> placed on the application of statistical techniques, rather than on discussion of the results of ordering and examining the data and on the inferences which should be drawn in the light of the context in which the data have been collected. The work can therefore become dry and tech... ...e-oriented and fail to show the power and nature of statistics.

What progress has been made?

In 1949, acting upon a resolution in the United Nations urging Unesco and the International Statistical Institute (ISI) to take appropriate steps to further the improvement of education in statistics on an international scale, the ISI's Committee on Statistical Education was founded. With financial support from Unesco, the Committee (Gani, 1988) provides statistical information, trains statisticians at training centres, notably the International Statistical Education Centre in Calcutta, and organizes round-table conferences on teaching aids, methods and curricula which are reported in the *Review of the International Statistical Institute* (ISI, 1971). A Task Force on the Teaching of Statistics at the School Level founded the journal *Teaching Statistics* with the aim of helping

> teachers of geography, biology, the sciences, social science, economics, etc., to see how statistical ideas can illuminate their work and to make proper use of statistics in their teaching. It also seeks to help those who are teaching statistics and mathematics with statistics courses. The emphasis of the articles is on teaching and the classroom. The aim is to inform, entertain, encourage and enlighten all who use statistics in their teaching or who teach statistics.

The journal's editor for the first eight years, Peter Holmes, was highly successful in achieving these goals. Another task force has organized two International Conferences On Teaching Statistics, in Sheffield, United Kingdom, in 1982 and Victoria, British Columbia, in 1986, each with about 500 participants. The meetings' proceedings are prime sources of information about statistics teaching worldwide. To support professional statisticians, the ISI, founded in 1885, publishes abstracts and reviews, and convenes biennial statistics congresses which are reported in their review.

Statistics used to be taught only at university level, with little more than the basic measures of averages for secondary schools. Now many school-leaving examinations contain a statistics option, even at the advanced levels. But the greatest changes have been in the primary school, where pupils now gather data, display it in various ways and draw inferences. In Hungary, statistics has been taught in the first four years of primary school for many years. Varga (1983 describes how combinatorics and probability are taught using a probability kit. Pupils

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make experiments about random phenomena by first predicting the outcome, then performing the experiment, and finally comparing the result with the prediction. In seeking explanations, some ideas in probability are developed. The present project in Italian primary schools was inspired by this Hungarian programme.

More recently, Exploratory Data Analysis has found its way into classrooms with pupils as young as seven years old. Using stem-and-leaf displays of data they collect, pupils derive new information. The use of stem-and-leaf displays does not remove the individual data values, yet still shows the structure of the set. Older students using box-plots, rearrange the representation of data and focus upon particular aspects so that the underlying structure of the data is teased out and new hypotheses can be formulated.

Some of the best examples of applications of statistics and probability in real-life situations were prepared by the NCTM and the American Statistical Association (ASA) Joint Committee on the Curriculum in Statistics and Probability. The resulting books (Tanur et al., 1972; Mosteller et al., 1973) were intended for readers with little knowledge of statistics or probability, and their style of presenting a situation and exploring the data for solutions is to be found in many subsequent books. The Joint Committee is also responsible for the Quantitative Literacy Project for students aged 12 to 14.

It is often heard that statistics and probability should be taught only to the better students, reserving for poorer students more fundamental ideas, but statistics is now considered a basic skill. For instance, Cockcroft (1982) included statistical ideas in their foundation list of mathematics topics for the lowest 40 per cent of the range of attainment in mathematics. They would develop in these students a critical attitude to the statistics presented in the media, an appreciation of the basic ideas of randomness and variability, an awareness of the relevance of probability to occurrences in everyday life, and an understanding of the difference between and purpose the of various measures of average.

Increasingly the physical, biological and social sciences are using probabilistic measures; hence statistics is coming into the school curriculum in these subjects. The advent of scientific pocket calculators which easily perform statistical calculations, has resulted in school subjects in addition to mathematics to apply more statistics. This trend will increase with the wider availability of calculators that not only make the usual statistical tests and calculate the coefficients for the regression line or curve, but also generate on their liquid-crystal displays (LCDs) the 'best-fit' curves. Calculators as mini 'number-crunchers' have made possible the use of data from real-life situations, allowing students to collect and analyse their own data rather than textbook data which always 'come out even'. Simulation and random experiments (like random walks), data analysis and calculating probability distributions are all more easily carried out, indeed possible, with a calculator.

Who should teach statistics now that it is found in so many school subjects? Many chapters in this volume stress the importance of examining data and drawing inferences rather than emphasizing the application of statistical techniques. Some claim statistics is too important a part of general education for its teaching to be left to mathematics departments. Because of the desirability of co-operation between all those who make use of statistics in their teaching, Cockcroft (1982) suggests that in each school a staff member, not necessarily a mathematics teacher, be nominated to co-ordinate. We have lately seen similar suggestions concerning microcomputer co-ordination.

Microcomputers now have available statistical packages which with a touch of the finger give most statistical measures of the data with many choices of nearly automatic visual displays such as scatter diagrams with their linear or higher order least-square fits, charts and many types of graphs. Our difficulties are no longer in calculating these measures, but in interpreting them. Computers have changed ways in which data are collected, stored, analysed, graphically displayed and communicated. Computers, especially microcomputers, offer us new ways of teaching statistics (Swift, 1984). This has so altered both the ways in which statistics is used and how it may be learned that the ISI devoted its 1984 Round Table Conference to the teaching of statistics in the computer age (Råde and Speed, 1985).

The teaching of statistics is not uniformly distributed across all countries. We have seen that some countries offer their students a general introduction to the subject beginning in primary school, continuing into secondary education as part of their general education, with possibilities given for more in-depth studies in the senior secondary classes. Some other countries offer almost no statistics. An international study which is reported in Barnett (1982) has been carried out by the ISI to determine the status of statistics teaching. Reports of an earlier international survey and case-studies from Austria, France, Nigeria, and Romania are given in Råde (1975). The two ICOTS Conferences and the International Congresses on Mathematical Education have heard a number of national reports which are included in their respective proceedings. These references contain many descriptions of national programmes of statistics teaching so they will not be repeated in this volume. But, as is customary in *Studies in Mathematics Education*, a more detailed national case-study is presented, in this case Italy. Cutillo, D'Argenzio and Pesarin have presented the new primary and secondary-school statistics and probability programme and the accompanying teacher-education schemes.

Implications for teacher education

This topic was treated briefly in Volume 4 of *Studies in Mathematics Education*, where Lennart Råde, in assuming that statistics teaching in schools will be within the mathematics curriculum, calls for statistics and probability to occupy between 15 and 25 per cent of teacher-education subject-oriented courses. Råde claims the amount of mathematics would not diminish since the statistics courses would provide opportunities to use mathematics in an applied context. In the Italian case study this idea is underscored as they claim that the 'introduction of elements of descriptive statistics and the notion of probability provides a fundamental instrument for the development of a mathematical awareness of considerable interdisciplinary value'. Råde would include in a teacher education programme: the didactics of statistics, work with computers and calculators, mathematical model-building of situations with elements of uncertainty and project work. Following the principle of 'learning by doing', the above processes would be learned by including project work and model-building of real situations in the programme. In Italy, they found that in degree courses in science, and even mathematics, no provision is made for the compulsory teaching of statistics and probability, and when they are included as optional subjects, they are geared to research and not towards teaching in schools. An Italian experimental programme was begun a decade ago for the better preparation of teachers in training for the new syllabus, which includes substantial amounts of probability and statistics at primary and secondary levels. A fundamental difficulty in teaching statistics, according to Steinbring, is that students are brought up with a deterministic view of the world, one which has unique answers based upon deduction. Statistics is concerned with inference rather than deduction, where several different inferences may be drawn from a set of data, each with different likelihoods of being true.

For those who are to teach subjects using statistics, some training in statistics must be given. Many students of these subjects will have had no prior statistics and hence their teachers must be prepared to introduce statistical methods. And for all other teachers, if they are to develop in their students the critical approach to data which has been advocated, some training in statistics will be required. Few practising teachers have had an adequate probability and statistics education, so in-service courses should be provided. In the United Kingdom, the Schools Council Project on Statistical Education (Holmes, 1983) developed materials for in-service courses, which were organized in regional centres set up for that purpose. Statistical co-ordinators appointed to develop interdisciplinary co-operation in their schools were given workshops and continuing support from these centres.

This chapter began with a look at the newspapers. Let us end with the response of one of the more influential statistics educators (Swift, 1983) who, when asked the question, 'Does the mathematics curriculum reflect the world in which we live?', after looking at this world through newspapers, called for the use of newspaper clippings in the classroom both to learn about the everyday use of statistics and as a source of problems leading to further investigations in statistics. With exploratory methods of looking at and analysing statistical data, we may educate all our future adults to take their place in collective and individual decision making.

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THE EVALUATION OF TERATOGENIC RISK IN THE FAMILY PLANNING CLINIC

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I am a medical doctor, my speciality is medical genetics and teratology. One of our main activities is to prevent congenital anomalies by counselling of families in our Genetic and Teratologic Clinic. I would like to highlight some of the teratological dilemmas connected with risk from our everyday work which cause both practical and ethical problems.

It is important that we speak a common language so first I shall define some terms.

In the narrow sense, teratology is the study and prevention of those congenital anomalies developing in the period of fetal development caused by environmental factors.

Counselling of families is based on risk assessment and risk management. Risk assessment involves three steps:

1/ Exposure assessment - in particular I want to deal with drug ingestion during pregnancy
2/ Hazard or outcome identification, i.e., congenital anomalies
3/ Risk estimation - the teratogenic risk is the probability

of the occurrence of congenital anomalies after a given exposure, e.g., the use of a given drug during pregnancy. It is based on observational studies thus we talk of empirical risks.

The risk management again involves three items:

1/ Information - the counsellor informing the counsellee about the risk and options

2/ Confirmation of understanding

3/ Continued support of the counsellee after they have made a decision to prevent or reduce their specific risk.

The emphasis of my presentation concerns the second point of risk management and it has five different aspects.

I. Some counsellees are unhappy to face the risk

All actions have benefits and risks. However, the majority of people focus their attention on desired aim and to forget risk. When couples plan to have a baby they frequently say: "We want to have a perfect baby", that is, of course, they hope to deliver a healthy fetus. However, we, counsellors, have to tell them that there is a so-called random risk of having a malformed baby. This is about 3%. Several couples are upset after this information because they have considered only rosy possibilities. Surely awareness of this random-background risk may contribute to decisions to reduce the number of children. Furthermore lack of understanding of such a risk produces unnecessary anxiety in pregnant women and can overshadow the joy of pregnancy. In general a long discussion is needed to explain that it is not possible to exclude random risk, at best we can reduce it by 'optimal family planning' and after this the low random risk is usually considered acceptable.

II. Sometimes the risk of a not-serious problem is exaggerated

Tetracycline is a useful drug in the treatment of infectious and inflammatory diseases. These illnesses may occur during pregnancy too. It became apparent that tetracycline can across the placenta and be deposited in bone. It may cause discoluration of teeth. However, this only effects the milk /first, deciduous/ teeth, not the permanent teeth. There is about a 20% risk for discolouration of first teeth after a long intake of tetracyclines in the second half of pregnancy. It does not appear to be a serious problem and it is acceptable if the treatment of the maternal disorder is appropriate during pregnancy. However, the misunderstanding of this risk causes at least two dangerous consequences. On one hand, the necessary medical treatment of the mother during pregnancy is neglected and may contribute to a great severity of her illness. On the other hand more than hundred planned pregnancies each year are terminated on the basis of so-called medical indication but without reasonable justification. If we screened the adult population, many people with discoloured teeth would be detected, e.g., smokers with their yellow teeth. I do not believe that society feels such people should be exterminated. Such ignorance about risks and consequences leads on to the next point.

III. Inappropriate risk management

In general medical doctors are sought out because of the possible consequences of a concrete, i.e., specific risk. Our task is to do our best to exclude it or reduce it as much as possible. However, in our work we cannot neglect the above-mentioned random risk. Therefore we might say: "Your chances of having a child affected by a congenital anomaly is twice as high as that of other couples in the general population". It means a specific risk of 3% plus the random risk of 3%. Our responsibility concerns primarily specific risk. However, after even after medically correct advice has been given and specific risk prevented, the random risk means that 3% of our counsellees may have another anomaly. If this happens, parents could sue the counsellor for damages suggest professional negligence in court. This explains why I say that random risk is the Damocles'sword of our profession which hangs over our heads and sometimes falls.

Medical doctors are protected professionally and also legally against the occurrence of random risk,so it is not a real danger. Yet, the possibility of a lawsuit exists, which causes concern and could even ruin the reputation of a medical doctor. This anxiety provokes two different consequences. First, the practice of counselling in the West is restricted to providing information and support and refrains from directive counselling. /In general this motivation is not mentioned and mainly the general principle that 'the right to have children is a human right which must not be unduly influenced by counselling' is stressed./ The point is that this non-directive counselling method allows counsellors to avoid legal liability in cases where an anomaly results as manifestation of the random risk. Second, in Hungary many medical doctors feel that it is simpler to recommend termination of pregnancy when they are asked about the teratogenic risk of drug use during pregnancy. On one hand they are not well-informed in this area due to the inadequacy of their education. On the other hand they do not want to face the random risk. Termination of pregnancy helps to avoid the responsibility althogether. This is true. When we recommend the continuation of a pregnancy, the consequences of the random risk may occur at any time. However, each profession and each type of work has its risk. This applies also to medical work and, within it, to the work of medical geneticists. We must do our best to reduce such risks, but we must accept that some risk is necessarily associated with our activity and rely both on the laws of nature and on our own competence. Only unworthy amateurs can profess the warning often heard also in our country: 'if you do nothing, you risk nothing.'

IV. Unbalanced perception of different risks

Sometimes a drug use during pregnancy may have some true teratogenic risk. For example an antifolate metabolite, metothrexate has a teratogenic risk of about 5% mainly causes microcephaly, i.e., small skull. This drug is used for autoimmune disorders and cancer. In general after they are given accurate information concerning risk, medical doctors and treated mothers want to terminate their pregnancies.

Undoubtedly the beginning of life is the conception thus the termination of pregnancy means the killing of the fetus with a 100% risk. Thus, in these mothers' minds a 5% risk for a postnatal anomaly caused by the drug is more important than the 100% risk for prenatal death caused by human action. I know there are many arguments concerning the differences between pre- and postnatal life/the infant has a separate physical existence from the mother, it is more available to physicians for treatment and also that parental acceptance goes through a series of behavioural changes during pregnancy/. Nevertheless I am not sure whether a good balance is achieved when a 5% postnatal risk outweighs a 100% prenatal risk.

I can show you the attributable risk of different etiological categories in the origin of congenital anomalies based on Hungarian data:

Major genes /Mendelian inheritance/	6%
Chromosome aberrations	5%
Multifactorial /polygenic liability+triggering environmental factors/	50%
Teratogenic factors	4%
/Drugs	0.2%-1.0%/
Unknown	35%

Thus, in Hungary we would expect each year about 50 congenital anomalies caused by drug use during pregnancy. However, 1 000 pregnancies are terminated due to this reason. In my opinion it is a threatening misunderstanding of risk.

V. Help or violation of human rights?

As I mentioned, the so-called non-directive method is used in genetic and teratogenic counselling in the Western countries. It involves providing information about risk and available medical and personal options, but does not involve direct advice. We wanted to use this method in Hungary too. But our counsellees were not satisfied with us. They wanted to get - as they said - more help and not only 'information'. It means that they expected to get concrete advice on what to do. Generally medical doctors tell their patients what to do, i.e., when, in what doses and how to take the prescribed drug. Finally we developed a method which basically consists of advice given in an indirect manner relating it to ourselves, e.g., 'in your case I would undertake a pregnancy without any concern' when there is no real risk. This system works well. However, when I reported on our method in Heidelberg in 1978 at the

European Conference of Medical Geneticists, some experts from the Western side of Europe critized me saying they were not surprised that human rights were not respected in East-European countries anyway - but that our method was very inappropriate in the practice of medical genetics. I do not know who is right. It is possible that so far our country has not had a democratic social system and people have become accustomed to following the advice or command of the authorities in power. If this is the case, I hope that it will be modified in parallel with the recent beneficial changes in our political system. However, there is another argument. In risk management, as in other things, it is necessary to take into consideration the expectations of people given their local cultural circumstances. Right or wrong, Hungary is my country.

The fact that risk is never zero leads to the concept of acceptable risk. The pupils speak in "O or 1" terms. I start my first mathematical lesson by saying that every decision we make implies probabilities.

John G. Kemeny

MEDICAL DIAGNOSIS, IONIZING RADIATION IN PHYSICS EDUCATON

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1. Introduction

In recent years there has been a growing awareness to the importance of emphasizing the applicability and relevance of science to everyday life in school science courses. Consequently, teachers and curriculum developers have begun to produce learning materials which demonstrate practical applications and emphasize the role played by science in our highly technological society. Most of these courses are aimed at non-science oriented students. Science courses for students in the scientific streams have generally not followed these trends. This has led to a situation in which "serious science" and "relevant science" have become almost mutually exclusive (Piel 1981, Eikenhof and Swager 1984, Hodson and Prophet 1983). This criticism certainly applies to the Israeli high school physics curriculum (grades 9-12). This curriculum includes a wide variety of subjects such as optics, waves, mechanics, electricity and magnetism and some topics in modern physics. The program is concluded by two electives which are designed to introduce topics which go beyond the standard syllabus. The courses take a theoretical approach to physical phenomena, and there is not much emphasis on applications or on technological, physics related aspects. We therefore decided to develop a new physics unit and to introduce it as one of the elective courses taught in 12th grade.

The unit "Physics in Medical Diagnosis" aims to demonstrate a variety of aspects of applied science by means of an example. It presents a real life problem and an analysis of some of its practical solutions. The basic structure and content of the course are outlined in Figure 1. A detailed description of the unit and its rationale was presented previously (Ronen and Ganiel 1984).

Figure 1: Content and structure of the course

Part 1. Introduction of the problem

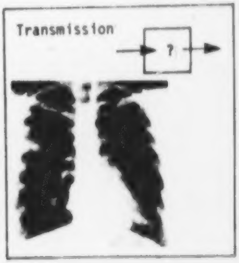
How to "look inside the human body" in a non-destructive manner.
Suggested solution: To use radiation (energy) which penatrates through the tissues. The emanating radiation carries some information on the structure or function of internal organs. Such information may be gained in different ways:

(1) By analyzing the radiation which is *transmitted* through the examined area.
(2) By inserting, in a selective manner, a source of radiation into the examined area and *tracing* the emitted radiation.
(3) By analysing the radiation which is *reflected* from the examined area.

Each of these methods is demonstrated by an example of a technique which is widely used in diagnostic imaging.

Part 2.

x-Rays



Part 3.

Radioactive Tracing

Part 4.

Ultrasound

Reflection
?

Parts 2, 3 and 4 have a similar structure, presenting:

- The relevant physical principles.

The imaging method, application and analysis of real data.

- The limitation and the constraints imposed by undesired physical phenomena, by the technology and by safety considerations.

Part 5. Discussion
General principles of non-destructive testing.

Visit to a hospital.

2. Special characteristics of the unit

The unit "Physics in Medical Diagnosis" introduces an example of applied science in a comprehensive manner. It aims at performing a fairly detailed analysis of the specific application of the physical principles to the solution of a given practical problem. Furthermore, it teaches students to consider the broader aspects involved in real life applications, such as technological limitations and safety considerations.

The unit has therefore some special characteristics which are different from those of a usual physics course in high school.

The basic physical principles and phenomena are assumed as prerequisites. They are only stated without the full elaboration given in regular physics courses.

Physical phenomena are dealt with in the manner in which they actually appear in the real world: different phenomena may occur simultaneously, and there may be an interaction between different phenomena. For example, the interaction of electromagnetic radiation with matter involves the occurence of both the photoelectric and Compton processes, according to probabilities which depend on the properties of the material and on the energy of the radiation. The understanding of these complex relations is necessary for analyzing and controlling the efficiency of the x-ray imaging technique. Furthermore, dealing with practical applications implies an integration of knowledge which is usually acquired in separate physics chapters, such as electricity, mechanics, optics or atomic physics. This integrative approach is emphasized in the course, in contrast to the isolated approach usually taken in the traditional physics lessons. In fact, for the student, this integration is by itself a "new physical phenomenon".

The problems and exercises presented in this unit do not necessarily have a unique quantitative solution. Rather, they may require broader considerations and application of optimization procedures. Furthermore, many problems are not "purely physical" since they involve the interference of technological aspects and safety considerations.

The unit includes a chapter on "the biological effects of ionizing radiation". This chapter introduces the basic concepts and provides quantitative information that will enable the students to comparatively evaluate the exposure doses from various sources. Also included in this chapter is a decision making game, which will be discussed in more detail below.

The course is concluded by a visit to a medical center, aimed to actually demonstrate the applications dealt with in the unit and to enable the students to address all their "medical" questions to professional experts (Ronen and Ganiel 1989A).

3. Ionizing Radiation - why deal with it in school?

During the first 3 years of implementation of the unit discussed above, the teaching and learning were monitored and evaluated in great detail.

During the initial phase of formative evaluation, we became acutely aware of certain issues related to the contents of the course, yet of more general implications.

In general, conventional science syllabi tend to shy away from areas of uncertainty which deal with social aspects of science, where scientists are not able to provide definitive answers. As a result, attitudes regarding science related issues are often shaped by information absorbed at home, from mass media, or from other incidental sources. Although this information may be strongly biased, incomplete, or even incorrect, people become accustomed to accept what they hear without experiencing it or understanding it for themselves.

Very often "we are quite unable, as a society, to distinguish between sense and nonsense when it comes to science" (Saxon 1983). Even "educated, intelligent, inquisitive people are unable to consistently bring informed judgement to bear on questions connected to science and technology, questions often vital to the welfare of each of us and indeed to the future of the world" (ibid, 1983).

The topic of ionizing radiation and its biological effects is a typical example. Its growing interference with everyday life, because of the widespread use of ionizing radiation sources in modern technology, and its controversial aspects, make it an issue of special interest (Howes, 1975; Lindenfeld, 1977; Eijkelhof, 1987).

Despite its relevance to everyone's life, and the large amount of objective scientific knowledge already in existence, this subject is usually avoided in traditional science courses for high school, and even in universities, thus allowing students no chance to present or confront their appraisals.

For example: The debate over nuclear power rages now more fiercely and less rationally than ever. We are exposed to strong and very determined opposite opinions on this issue. Whom are we to believe, and how are we to know?

One of the most important responsibilities of science educators is to make their students adopt an informed approach. By that we mean, that a person forming an opinion on a science-related issue should ask:

What kind of basic knowledge can help me form my own informed judgement?

Do I possess such knowledge?

What are reliable objective sources for the necessary information?

A very effective way to encourage such an approach is to make students realize the need for it, by themselves, through a personal experience. In the following section, we describe an example of such an experience.

4. The game "Beware-Radiation!" First stage: Appraisals

Subjects were asked to express their personal appraisals of different situations concerned with exposure to low levels of radiation (Figure 2).

The game questionnaire was given to subjects of different personal backgrounds: high school students who studied physics, students who did not study physics, high school physics teachers and educated adults with no scientific background. All subjects were initially asked to fill column I only. The grading pattern repeated itself consistently among all subjects.

Figure 2: The game sheet.

Beware - Radiation!

The following describes different situations which affect the level of exposure of a person to ionizing radiation.

Assume that situations B-H differ from the "Isolated Man" (A) *only* by the factor mentioned.

On a scale of 1 to 8 grade the situations A-H according to their total *annual* exposure to radiation. (1 - maximum exposure to 8 - minimal exposure)

	I Scaling (1-8)	II Estimate of annual dose (μSv/yr)	III Repeated Scaling (1-8)	IV |I-III|
A - An "Isolated man" lives on the beach (no modern technology available)	____	________	____	____
B - Watching TV for 8 hours a day	____	________	____	____
C - Living in Jerusalem (altitude: 800m above sea level)	____	________	____	____
D - Living near the Dead Sea (400m below sea level)	____	________	____	____
E - Living 10 km from a nuclear power station. (No accidents)	____	________	____	____
F - Having one X-ray of the chest taken once during the year	____	________	____	____
G - Taking a 3 month trip to the mountains (3000 m altitude)	____	________	____	____
H - Makes 5 transatlantic flights (20,000 km each) during the year	____	________	____	____

Analysis of variance (Table 1) revealed the following patterns:

A high exposure group including the "artificial sources" of TV, X-rays and a power plant, a second group including "rather unusual situations", and a third, lowest exposure group, including the "ordinary/daily" situations (Subjects used these definitions when trying to explain their initial gradings).

All students and most of the teachers reported that their gradings were "intuitive" but based on "well known facts..."

As can be seen from the sample analysis, grading intuitions turned out to be very similar, among subjects and between groups.

We found a single significant difference between teachers' and students' gradings: Teachers attributed higher gradings (lower exposure) to situation E (living near a nuclear power plant) than students. We can only speculate on the reason for this difference: Physics teachers are more knowledgeable about this particular technology than their students, hence regard it as less risky.

Table 1: Analysis of gradings

"Physics" Students (N=65)		"Non Physics" students (N=31)		Physics teachers (N=30)	
Situation	Grading Mean (S.D.)	Situation	Grading Mean (S.D.)	Situation	Grading Mean (S.D.)
B	2.6 (1.7)	B	2.3 (1.3)	B	2.3 (1.7)
E	2.8 (1.8)	E	2.3 (1.6)	F	2.9 (1.6)
F	2.9 (1.8)	F	2.8 (1.5)	**	**
*	*	*	*	E	3.6 (1.8)
H	4.1 (1.5)	H	4.6 (1.3)	G	4.2 (2.2)
G	4.7(1.9)	G	4.9 (1.9)	H	4.4 (1.5)
*	*	*	*	**	**
D	5.5 (1.8)	C	5.7 (1.4)	C	5.3 (1.5)
C	5.5 (1.5)	D	5.9 (1.3)	D	6.0 (2.0)

* Significant difference between groups ($p < 0.05$).

** No significant difference between extreme gradings of adjacent groups.

5. Ionizing Radiation and its Biological Effects - A class activity

The topic "Ionizing Radiation and its Biological Effects" was initially introduced as one of the chapters in the unit "Physics in Medical Diagnosis" described above (§ 2.). We found during the evaluation of the unit that this topic was of special interest. A typical student remark was: "This topic should be taught to *every student in all* schools".

Students and teachers' responses, including their gradings of situations involving ionizing radiation (§ 4.), convinced us that this material is indeed too important to be left to incidental teaching or even worse - to be totally negnected.

Thus, a short stand-alone class activity was developed, dealing with "Ionizing Radiation and its Biological Effects". This activity can be effectively introduced at any high school or college level, both scientifically or non scientifically oriented. The activity aims to:

* Introduce the basic concepts and terminology needed to deal knowledgeably, both qualitatively and quantitatively, with the subject.
* Make students realize the difference between beliefs and knowledge, encouraging them to seek the basic knowledge needed to form their own informed judgement on science related controversial issues.
* Demonstrate the limitations of science to provide definitive answers to some important questions and stress the nature of human choices and value judgements involved.

Description of the class activity

The activity is organized in the following stages (summarized in Table 2):

1) Introduction of the game sheet "Beware-Radiation". Students introduce their own appraisals (Column I of game sheet - Fig. 2).

2) Introduction of basic concepts and terminology, as concise answers to the following questions:

What is ionizing radiation, what are its sources, and what is the mechanism of its biological effects?

Table 2: Structure and content of class activity

Stage	Duration	Content	Activity
1	(5 min)	Beware-Radiation: Game-Sheet (Column I)	Individual activity
2	(50 min)	Ionizing Radiation and its Biological Effects: Introduction of basic concepts and terminology	Lecture/class discussion/ exercises
3	(10 min)	Beware-Radiation Exposure estimations based on information from the Information Sheet.	Individual/group assignment or teacher coordinated activity.
4	(10 min)	Evaluation of game results.	Free class discussion.
5	(30 min)	Estimates of effects of Low level radiation: a controversial issue. Safety measures.	Lecture/class discussion/ examples
6	(15 min)	Human choices and value judgements.	Open discussion

What are the possible immediate somatic, delayed and genetic effects of exposure to ionizing radiation? (qualitative aspects).

How do we measure exposure to radiation? - Definition of(rad and rem units and more recently) the Gray and Sievert.

What are the relevant factors affecting the biological response? (dose, kind of exposure, radiation source, duration, part of body exposed, critical organs) - A class discussion.

What are the estimates of biological effects of high doses? (radiation sickness, lethal dose, delayed and genetic effects).

What is the natural background radiation, its sources and quantitative estimates of exposure levels.

- What are the estimations of exposure levels from different artificial sources? (quantitative examples).

As already emphasized, the aim of this part is to introduce the basic concept and tools for dealing knowledgeably with the subject. We restricted ourselves to a purely informative approach. To ensure understanding of the concepts involved, students were challenged with questions such as:

* Which of the following exposures is more dangerous: 1 Gray to whole body, or 1 Gray to the arm?

This question tests the real understanding of the definition of the Gray unit. Both students and teachers seemed to have difficulties with answering this apparently trivial question.

* Estimate the rise in body temperature caused by the exposure of the whole body to the lethal dose (5 Gray). Assume that *all* radiation energy is transformed into heat. Use the specific heat of water (4.2 J/°C.g). The result (0.0012°C) causes much surprise: despite the previous explanation of the mechanisms of the biological effects of ionizing radiation, most subjects still seem to attribute a strong "thermal connotation" to radiation dangers.

3) This stage consists of a quantitative estimation of exposure doses for the different situations presented in the game "Beware-Radiation". The calculations are based on data presented in an Information Sheet given to the students (Table 3).

Participants fill out columns II-III of the Game Sheet. Column IV and its total, used for calculating the differences between initial and repeated scalings, introduce the competitive element of this activity.

Table 3

Information Sheet

ESTIMATES of exposure to radiation*

Source of radiation	Annual Dose (in 10^{-5} Sievert)
Cosmic radiation at sea level..........	30
Effect of elevation: for each 1800m elevation the exposure is doubled.	
For estimation of annual exposure to cosmic radiation at altitude h(m) use the relation:	$30.2^{h/1800}$
Natural ground average from minerals and construction materials	30
Food, water and air	30
Chest X-ray	10
Radiopharmaceutical examinations	300-500 (per examination)
Jet plane travel - for each 4000 km	1
T.V. viewing: For each hour per day	0.15
Nuclear plant (maximum allowable dose)	
At site boundary	5
8 km away	0.05
Over 8 km away	None

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* Revised from the BEIR Report (1980).

4) Reactions: Evaluation of Results.

This stage is a free class discussion, during which participants express their reactions, feelings, and conclusions.

We found that the first typical reaction was one of *surprise.* Then, when subjects realized the similarity of their initial gradings, there came the stage of "self evaluation". The following arguments are based on statements made by the participants themselves. Initially, subjects felt quite sure of their primary gradings, because at the time they believed them to be based on "well known facts ...". Later, having been exposed to the relevant information, they arrived at the conclusion that lack of any basic knowledge on the subject resulted in a "reconstruction of facts" in a manner which would match them to beliefs adopted previously. Since the sources for popular beliefs were similar, so were the "reconstructed facts" (for example: "Radiation from TV is dangerous..").

5) During the stage, the special problems involved in estimating the biological effects of low levels of radiation are presented. These include:

- Possible sources of information.
- The linear extrapolation theory and its limitations (quantitative example).
- Different opinions on this issue.
- Safety measures for radiation protection (maximum allowable doses).

6) The activity is concluded with an open class discussion. Controversial issues are brought up, and their complicated nature is emphasized. Various decision making processes include more than purely scientific considerations. Often, political, economical and other interests come into play.

All these questions, involving human choices and value judgements are left upon, suggesting further reading.

6. Attitudes towards energy related phenomena and occupational risks

As already mentioned, the unit "Physics in Medical Diagnosis" (§ 2.) was carefully evaluated during the first 3 years of its implementation (Ronen and Ganiel, 1989B). The evaluation made use of a variety of measurements: pretest and post-test questionnaires, detailed analysis of student achievements, classroom observation and interviews with students and teachers. Whenever relevant, the results were compared with those of a matched control group of 12th grade students who did not study this unit.

In the present paper, we shall limit our discussion to two aspects out of a larger variety investigated.

a. Perception of energy phenomena

One of the aims of the evaluation research was to check whether studying the unit had any effect on the perception of the energy phenomena dealt with in the unit: x rays, radioactive radiation and ultrasound.

We concentrated on two specific dimensions: the perception of the utility of the phenomenon, and the danger attributed to it.

Each student was asked to mark a position on a 7-point scale (semantic differential questionnaire) for each adjectival pair (safe-dangerous; beneficial-harmful) representing his/her attitude toward the energetic phenomenon.

Student responses reflect their immediate, associative attitude towards the concept; Only 3 (out of 269) students added remarks like: "it depends on the way you use it..."

This áttitude questionnaire was used as a pretest and as a posttest in both the experimental and control groups. The summary and analysis of student responses is given in Table 4, and presented graphically in Figure 3 for the experimental group.

Figure 3: The perception of energy phenomena

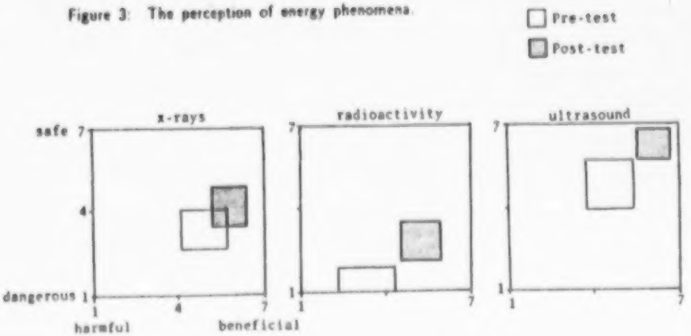

Table 4: Attitudes towards energy Phenomena

Experimental group: pretest N=147; post-test N=82
Control group : pretest N=123; post-test N=81

		beneficial (7) - harmful (1)			safe (7)-dangerous (1)		
		Experimental Mean (S.D.)	Control Mean (S.D.)	ANOVA for group means F (P)	Experimental Mean (S.D.	Control Mean (S.D.)	ANOVA for group means F (P)
X-rays	pretest	4.9 (1.6)	4.7 (1.7)	7.9 (< 0.01)	3.3 (1.4)	3.2 (1.5)	9.8 (< 0.005)
	post-test	5.8 (1.3)	4.9 (1.6)		4.1 (1.4)	3.3 (1.3)	
Radioactive radiation	pretest	3.4 (1.9)	3.3 (2.0)	45 (< 0.0001)	1.5 (0.8)	1.5 (0.8)	40.9 (< 0.0001)
	post-test	5.2 (1.4*)	3.2 (2.0)		2.8 (1.3*)	1.6 (0.8)	
Ultrasound	pretest	4.6 (1.8)	4.6 (1.7)	43.3 (< 0.0001)	4.7 (1.7)	4.6 (1.7)	50.5 (< 0.0001)
	post-test	6.1 (1.1*)	4.5 (1.7)		6.3 (1.0*)	4.6 (1.7)	
Laser	pretest	5.6 (1.7)	5.1 (1.9)	1.44 (NS)	3.0 (1.7)	3.2 (2.0)	0.13 (NS)
	post-test	5.6 (1.4)	5.4 (1.9)		3.7 (1.8)	3.7 (2.0)	

* Significant differences between pretest and post-test variances in the experimental group ($p < 0.01$)

No significant differences were found in *pretest* attitudes between the groups, or between pretest and postest responses of the control group.

No significant change occurred in the perception of Laser radiation - a phenomenon that was not mentioned in the new unit. However, the pre/post analysis reveals significant changes in the way students from the experimental group perceived the energy phenomena dealt with in the unit (Table 4, Figure 3). In general, after the study phenomena were regarded as more beneficial, and were perceived as safer (or less dangerous) than before. Furthermore, there were some significant changes in the distribution of student responses. These changes were found in the following dimensions:

After the study radioactive radiation was still perceived as the most dangerous phenomenon (though less dangerous than before), but the unanimity of responses (reflected in the smaller S.D.) was less pronounced.

After the study ultrasound was perceived as the safest and most useful phenomenon. The distribution of opinions on both dimensions was significantly reduced.

The changes in student perception of these energy phenomena were apparently a result of studying the new unit which deals with beneficial and constructive applications.

The different impact on student perception of the different phenomena can be attributed to the gaps between knowledge acquired during the study and students' preconceptions. The large effects (on means and distribution) on the perception of ultrasound are probably a result of the relative ignorance of the students about this subject, prior to the study of the unit. The large effects (on means and distribution) on the perception of radioactive radiation are probably a result of strong negative preconceptions as well as lack of knowledge. The smaller effects on the perception of x-rays can be attributed to the fact that their application is familiar from personal experience. Previous perceptions are already rather balanced, and the realization of the utility as well as the awareness to possible hazards were already present prior to the study.

Detailed analysis revealed another interesting aspect. We found a (Pearson) correlation of

0.4 (p=0.0006) between the "danger" gradings for x-rays and radioactive radiation in the post-test gradings of the experimental group. All the other correlations between the gradings of the different phenomena, in both groups, were practically zero. This correlation, which appeared only *after* the study, is attributed to the identification of both phenomena as ionizing radiation, having the same mechanisms of biological effect.

b. Occupation Risks

Another question which was studied in the evaluation research was: Is there any change in student perception of the occupational risk of professions that might involve exposure to radiation, as a result of studying the unit?

Students were asked to grade eight given professions according to their occupational risk, before and after the study (1 - highest risk, 8 - lowest). The gradings were compared to the control group responses (Table 5).

In the pretest, professions that were perceived as related to exposure to radiation were attributed the highest risk level by both groups.

No significant differences were found between experimental and control group pretest gradings or between control group pretest and post-test gradings.

A number of significant changes were found, in the post-test, in the experimental group gradings. The "radiation related" occupations were perceived as relatively less dangerous than before, while the relative occupational risk attributed to flight attendant was higher than before. This last change can be specifically attributed to studying about cosmic radiation and its characteristics.

7. Concluding Remarks

The unit "Physics in Medical Diagnosis" was designed to introduce some important aspects of applied science into the high school physics curriculum.

We wish to emphasize that this is not a soft science unit, nor does it replace studying basic physics. Its special importance is due to the opportunities it provides for students to deal with practical, real life applications of physical principles is an interesting, human context.

Table 5: Occupational risk gradings

	Experimental group N=97			Control group N=104		
	Occupation	Mean (S.D.)	Grouping*		Mean (S.D.)	Grouping*
Pretest	Engineer at a nuclear power plant **	2.3 (1.8)	A	Engineer at a nuclear power plant	2.9 (2.2)	A
	Pilot	3.6 (1.9)	B	Pilot	3.0 (1.7)	A
	Policeman	3.7 (1.9)	B	X-ray Technician	3.9 (1.9)	B
	X-ray Technician **	3.7 (1.8)	B	Policeman	4.1 (2.0)	B
	Construction worker	4.6 (1.9)	C	Construction worker	4.3 (2.0)	B C
	Taxi driver	4.7 (2.0)	C	Taxi driver	4.8 (1.9)	C
	Flight attendant **	6.1 (1.6)	D	Flight attendant	5.8 (1.9)	E
	Physician	7.1 (1.3)	E	Physician	7.1 (1.3)	F
Post-test	Pilot	3.1 (1.9)	A	Engineer at a nuclear power plant	3.3 (2.4)	A
	Flight attendant **	3.8 (2.0)	A B C	x-ray Technician	3.5 (2.0)	A
	Taxi driver	4.2 (2.6)	B C	Pilot	3.5 (1.7)	A
	Policeman	4.3 (2.3)	B C	Policeman	4.1 (1.9)	B
	Construction worker	4.4 (2.3)	B C	Taxi driver	4.3 (2.2)	B
	x-ray Technician **	4.8 (1.9)	B	Construction worker	4.4 (1.9)	B
	Engineer at a nuclear power plant **	4.9 (2.3)	B	Flight attendant	5.6 (1.7)	C
	Physician	6.5 (1.5)	D	Physician	7.2 (1.4)	D

* DUNCAN grouping: No significant differences between groups marked by the same letter.

** Significant differences between pretest and post-test gradings ($p<0.01$).

Our evaluation study revealed that the new unit was implemented successfully and was integrated well into the existing physics program. Its level of difficulty was found to be similar to that of conventional topics like Mechanics, and students' achievements in the unit were relatively high and in correlation with their achievements in other topics in physics. This new unit was evaluated by the students as the most interesting topic taught in their physics program. The special interest was attributed to the applicability and the relevance of the subject to every day life.

The pre/post study showed that learning the unit affected the way students perceived energy phenomena dealt with in the unit. In general, after the study the phenomena were regarded as more useful and less dangerous than before. As to the danger attributed to ionizing radiation, we found that extreme opinions were moderated while the range of opinions was diversified. This effect is attributed to the study of the chapter on the biological effects of ionizing radiation, during which the students were exposed, for the first time, to the basic terminology and to some quantitative information on this subject.

One of our most important roles as science teachers is to prepare our students to contribute effectively as informed members of modern society. We would like to argue, that a missing ingredient in our science curricula is the link between pure scientific knowledge and the way it may affect our opinions and value judgements on controversial science related issues. Such a link can be created by stressing the practical value of scientific knowledge. Even short, stand-alone activities like the one described above (§ 5.) can serve this purpose. Such activities contribute to the interfacing between science and real life, help to convince students of the practical value of scientific knowledge and may be effective in encouraging informed judgement on science related issues.

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PUPIL'S PERCEPTION OF RADIATION RISKS AND ITS RELEVANCE FOR EDUCATION

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1. Introduction

In the last decade a number of studies in social science have been devoted to risk perception of the public. What we mean with 'perceived risk' is well described in a study group report by the Royal Society:

> "the combined evaluation that is made by an individual of the likelihood of an adverse event occurring in the future and its likely consequences" (Royal Society, 1983, p. 94).

These risk perception studies examine the judgments people make when they are asked to characterise and evaluate hazardous activities and technologies.
An example of such a study was reported by Slovic and his colleagues (1979). They compared the risk ratings of lay-people and experts on thirty different activities and technologies according to the present risk of death from each. The activities included for instance smoking, nuclear power, police work, X-rays, power mowers and vaccinations. It was found that nuclear power was judged as extremely risky by the public and far less risky by the experts. Rather the opposite was found on X-rays: they were seen as quite risky by the experts and much less risky by the public.

Comparable results about the differences in risk perception on X-rays and nuclear power among secondary school pupils were reported by Eijkelhof (1986) and by Ronen and Ganiel (1989). They both reported some changes in risk perception due to education.
Limitations of these studies are that they do not provide much insight into pupils' beliefs underlying risk perception nor into reasoning on radiation risks, and that they are limited to only two contexts: X-rays and nuclear power. In this paper we will report some of our recent work trying to overcome these limitations. To this end we interviewed pupils about the risks of radiation in a variety of contexts in an effort to get more insight into their ideas and ways of reasoning before they received education on this topic in physics classes.

2. Interviews among pupils: research procedure

We interviewed 15 groups of two pupils about their ideas about radiation (affective and cognitive). Each group was asked questions about three contexts out of a set of five: background radiation, medical applications, nuclear power (Chernobyl), the storage of nuclear waste and food irradiation. The questions were of an open nature and could not be answered simply with 'yes' or 'no'. At some points in the interviews, photographs (e.g. of an X-ray department, irradiated food, a food irradiating room and radioactive waste vessels), drawings (e.g. of a pie chart on background radiation) and short newspaper cuttings (e.g. on irradiated food, Chernobyl and radon in homes) were shown as illustrations to certain questions. When

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the interviewer did not understand an answer, he added some questions in order to clarify pupils' ideas.
Interviews were held with groups of two pupils, partly to set pupils at ease, partly to stimulate additional comments on each other's answers and to promote discussion between them. Trial interviews with groups of three pupils were not successful as it took too much attention from the interviewers to keep interviews going in a proper way (i.e. following the interview scheme, watching the time, and taking care that all pupils contributed). It was also difficult to decipher who said what on the tapes. Each interview took approximately one hour and was held after the last lesson of a school day.
Pupils were selected from five schools in and around Utrecht. A physics teacher from each school selected groups of form 4 pupils taking care that these pupils were not too quiet nor exceptional in ability. Pupils received a small reward for their participation.
In this way 15 interviews took place in the period from April 7 to June 9, 1987. At each school three interviews were held at the same time in different rooms.

After the interviews the tapes were transcribed by an administrative assistant into protocols. The interviewers compared the protocols with the tapes and made corrections where necessary. The revised text of the interviews was cut into parts and categorized according to contexts. For each category we noted the variety of specific answers until no new answers could be found. After this, for each context the answers were summarized. Checks were made by colleagues to correct for incompleteness, incorrectness and dubious interpretations.

3. Interviews among pupils: results

We confine ourselves here to the results of the interviews regarding risk perception. The following summaries describe pupils' ideas about the risks of ionizing radiation on each of the five contexts.

A. CHERNOBYL

Chernobyl was seen as a serious accident, especially for those living in the countries of Eastern Europe ("one million of ill people", "miscarriages"). Some referred to personal experiences such as the cancelling of a holiday in Eastern Europe, the throwing away of vegetables from the home garden, and not buying any fresh vegetables for some time.

B. MEDICAL APPLICATIONS

X-rays were in general not perceived as very dangerous. Pupils made remarks like:

"they only use X-rays when it is necessary"
"one X-ray picture is not dangerous, only many are".

A minority saw some hazards in X-rays:

"X-rays must be dangerous as my mother and the nurse had to stand behind a special window"
"pregnant women need to be careful with X-rays".

Pupils expected more risks for members of staff in hospitals, with some comments like:

"not such that they will get cancer"
"they opt for the risk".

Reference was also made to safety measures such as the use of lead screens.

These measures are also the reason that most pupils would not fear working with radiation in a hospital. Some expect that if you work with it for years you will contract something, as some of the radiation will always get past the protective clothing and as there is a chance of making mistakes.

C. RADIOACTIVE WASTE
Radioactive waste was considered to be dangerous by all pupils:

> "you don't see it, you don't smell it, but you notice it in a certain way"
> "after many years it has spread in such a way that it doesn't give any more trouble, but still it is not healthy"
> "normal waste could decay, but radioactive waste remains for ever, or at least for a very long time"
> "the waste has been irradiated, so the radiation could be released".

Most pupils were opposed to storage of this kind of waste in their neighbourhood because of the possibility of accidents or because "something will always pass". One pupil had no objection as "it will be well packed". Burning of the waste was not favoured by any of the pupils as "you will blow radiation into the air", "the radiation does not disappear during burning", "otherwise they would have done it already" or "it is too expensive".

D. FOOD IRRADIATION
Many pupils would never buy irradiated food, would prefer less good looking food that has not been irradiated, or find food irradiation unnecessary as "there is enough fresh food available". They feared that by consuming this kind of food you receive a little bit of 'it' and "many small ones add up" or that not all bacteria would have been killed. A minority however, would not mind eating irradiated food. They think that it is not dangerous "otherwise they wouldn't do it", rely on research done, are not afraid of contamination, assume that only small amounts of 'it' are used and that these quantities are quickly broken down by the human body. One pupil adds that it would be a bit harmful but the same applies to smoking so you should not bother too much.

E. BACKGROUND RADIATION
Background radiation was not perceived to be dangerous by a majority of the pupils:

> "background radiation has a low concentration"
> "artificial radiation is more dangerous than natural radiation as the latter has always been with us and I never had any trouble with it"
> "natural radiation remains in equilibrium, some is added, some goes away"
> "background radiation is only dangerous when it comes from Chernobyl".

A minority did see some hazards in this kind of radiation:

> "background radiation makes people old"
> "background radiation breaks things down"
> "radiation from the soil is most dangerous as we live nearby it and we cannot change that".

Our conclusion is that pupils' risk perception of ionizing radiation strongly depends on the context. We assume that the following factors may be important for risk perception:

> a. the function of the radiation: if it is used for a purpose it couldn't be as bad as radiation which has no function [medical radiation versus radioactive waste and Chernobyl]; if the need is not seen it should not be used [food irradiation]

b. the number of times and ways in which the newspapers have reported about issues [Chernobyl and radioactive waste]
c. the natural character of radiation: 'natural' seems to have a positive connotation [background radiation].

Less context-specific results of the interviews were that we found that many examples of pupils' reasoning were not based on scientific knowledge but on a common sense form of argument. The following examples deal with the risks of radiation. Reasons which pupils gave for considering a certain application of radiation dangerous include:

"X-rays must be dangerous as my mother and the nurse had to stand behind a special window"
"apparently it is more dangerous besides the beam [of X-rays] than in the beam" [as nurse has to stand behind screen and patient not]
"if it [irradiation of food] happens in a room like that they couldn't say it is not dangerous"
"rather tricky, if you see what is required to keep it from the open air"
"if you look at how the workers [in a food irradiation plant] have to be protected with special clothing, it could not be right for an apple to receive a dose of radiation".

These pupils conclude from the existence and nature of safety measures that there must be something dangerous about that kind of radiation.
Others take the opposite view about the risks of applications of radiation using the following arguments:

"you don't notice anything so it [X-rays] can not be bad"
"otherwise they wouldn't do it [irradiation of food]"
"otherwise they wouldn't use it [building materials releasing radon]".

These pupils use two kinds of arguments to defend the safety of an application of radiation. One is that they have no personal experience of it, perhaps meaning that they never heard of any hazards associated with it. The second argument is that if anything is done there will be a good reason for it. These pupils rely on the wisdom of those who work with the radiation or on official safety measures.

All these quotes about hazards and safety indicate that pupils use non-scientific ways of reasoning in weighing radiation risks. For them current practice is the source of their reasoning and they draw their conclusions from it. It often looks as if they already have a particular attitude towards the risks of radiation from which they interpret new evidence and answer questions. Their reasoning seems to be directed towards justification of their attitude.
Among pupils we detected two polar kind of attitudes:

a. radiation is always dangerous
Pupils who have this attitude tend to reason that radiation is permanent and would never disappear completely; in their view all kinds and all amounts of radiation are dangerous; from the safety measures in various contexts they draw the conclusion that the radiation must be extremely dangerous as otherwise these precautions would not be taken.

b. the risks of radiation are limited
Pupils having this attitude tend to reason that radiation decreases and could drop below a safety level; in their view small amounts of radiation (especially X rays) are not dangerous at all

and could be broken down by the human body; safety measures are seen as signs of control as otherwise they would not have been taken.

4. The relevance of these results for education

In summary, in many pupils' answers we detected common sense forms of reasoning which we could label as 'reasoning from practice'. Pupils draw conclusions which seem logical to them as they are based on the function of radiation, on personal experience or on the existence of safety measures or protests about safety. One could argue that this kind of reasoning is a result of the context of the interviews, in which an expert (the interviewer) asks questions about a field with which the respondents are not very familiar. So we cannot be sure whether the pupils had these opinions already or invented them on the spot in order to satisfy the interviewer or not to look too ignorant. Although we do not deny that this is a problem, the number of occasions on which we found this kind of 'reasoning from practice' is quite large. So we feel justified in defending the hypothesis that this kind of 'reasoning from practice' is relatively common among pupils. It may be derived from common culture (Arca, Guidoni & Mazzoli, 1983; 1984) and reflect a kind of natural thinking which drives behaviour within a context according to a purpose and allows people selectively to disregard information (Guidoni, 1985) and to suspend doubts about the 'reality' of the world (Schutz & Luckmann, 1974). This way of thinking may serve goals that are more important and fundamental than holding correct views about particular issues (Nisbett & Ross, 1980). If so, it is likely that this 'reasoning from practice' may seriously interfere with learning and especially with educational efforts to relate scientific knowledge to everyday life. More research is required to reveal the nature and importance of this way of thinking if we want "acquired knowledge to become flexible, comprehensible, organizable, applicable, sharable, i.e. useful, to the individual, to the group and to society" (Arca et al., 1983).

One may expect that pupils with attitude a ('radiation is always dangerous') tend to resist more to assimilate scientific information than those having attitude b ('the risks of radiation are limited'), as scientific information is often used to delineate risks.
Another relevance for education may be that a teacher should recognize that various views about the risks of radiation exist in class. These views are likely not to be superficial but are based on some general attitudes towards risks and are reinforced by certain preconceptions (Lijnse et al., in press) and by reports in the media (Eijkelhof and Millar, 1988). Such differences of attitude could be an asset in fruitful discussions about radiation risks, but could also have a negative impact on those discussions if not well managed. In our view a teacher should try and seek ways to increase pupils' ability to assess radiation risks, without attacking particular attitudes, but allowing pupils to change attitudes at a rate and in a direction which they prefer.

The context dependent character of risk perception suggests that pupils may not change their way of thinking about radiation if ionizing radiation is only dealt with in one particular context and if the social sources of the beliefs underlying these perceptions are neglected. It may be worthwhile, therefore, to pay attention to a number of different contexts and by including an analysis of newspaper articles in class.

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TEACHING ABOUT RADIOACTIVITY AND RISK

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I think there are some good reasons to pay attention to risk aspects in education about radioactivity. These reasons are:

- pupils are strongly interested in questions about risks and safety regarding ionizing radiation; this is not specific for pupils: analysis of the kind of questions asked by the public during nuclear incidents shows that people would like to know what kind of risk they run and how they could protect themselves; in other words, one may expect that such an approach will motivate pupils: a good breeding ground for education
- risks of ionizing radiation appear very frequently in the everyday world of media reporting; especially applications of radioactivity are surrounded by some controversy and public debate; if one aims teaching at scientific literacy, which in my view means that pupils should be able to use scientific knowledge in daily life, pupils should learn to understand the points at issue in these debates and be able to assess the risks of using ionizing radiation; in other words: a good output of education.

With these reasons in mind we wrote eight years ago a unit aiming at pupils learning to assess the risks of ionizing radiation, as part of the PLON curriculum (Eijkelhof and Kortland, 1988). Then we evaluated pupils' learning and detected some serious teaching and learning problems which were new to us. We decided to study these problems in depth during the last three years. By now we know much better what the problems are, where they come from and how serious they are. We have some ideas about solutions and are planning to write a new version of the unit in order to see what results we get once these problems are taken into account. So this lecture is not a victorious report of how well the unit went, how happy all teachers and pupils were, how much they learned from the unit and how much the unit is recommended by pupils to their peers. It is also not the opposite, because that would also be a distortion of the truth.
I prefer to give a research based account of the problems one might face when teaching ionizing radiation in the risk assessment perspective and some suggestions for solutions about which I do hope a discussion arises during this conference. I do hope so, as I sometimes think the problems are bigger than we are able to solve on our own.

2. Current practice in schools

Teaching ionizing radiation with the aim of pupils learning to assess the risks of applications of ionizing radiation is not common. The common approach is rather academic: one starts with the nucleus, with instable nuclides and with the characteristics of various kinds of ionizing radiation. It looks as if learning about nuclear physics is an aim in itself or only a preparation for further studies in the field of nuclear physics. Little attention is paid to those aspects which do relate to what interests pupils most and which at first sight seem to be required in order to be able to understand points at issue in personal life and in public debates: the effects of radiation, the usefulness of safety measures and the risks and benefits of certain applications.

So the common approach to teaching radioactivity is not very well adapted to the aim of scientific literacy: knowing how many protons and neutrons remain in a nucleus after the emission of a β-particle to me does not seem to be the most relevant knowledge for an average citizen.

3. An alternative approach

In the PLON-unit Ionizing Radiation (PLON, 1984) we followed a different approach. Starting point was our aim that pupils should learn to assess the risks of ionizing radiation. In addition to the physics of nuclear sources and ionizing radiation a great deal of attention has been paid to dose-effect relations, to safety measures, to applications which pupils might meet in daily life (nuclear energy, nuclear arms and radiation in hospitals) and to procedures of risk assessment.

This approach appeared to be very popular among pupils (Eijkelhof, 1986), especially the sections on health radiation among girls (Jörg and Wubbels, 1987). Nearly all pupils found the unit interesting because of its attention paid to the effects of radiation and to radiation protection. Also teachers were in general very satisfied with the unit: if we would just listen to them only minor changes would be required to make the unit more or less ideal.

However, a closer look at the learning results of about 100 pupils through pre- and post-tests in which pupils were asked to give comments on risk bearing situations, showed the following (Eijkelhof, 1986):

- in their reasoning they hardly used scientific knowledge from the unit, such as the physics of nuclear sources and ionizing radiation, dose-effect relations and safety measures
- they failed to apply risk assessment procedures as dealt with in the unit, especially in areas with which they were already somewhat familiar before teaching, such as the disposal of nuclear waste
- pupils used some lay-ideas about radioactivity and ionizing radiation, both before and after teaching the unit, some of which were reported before by Riesch and Westphal (1975).

Apparently, satisfaction with a unit by teachers and pupils is no guarantee for reaching the aims of learning. Our general impression was that ideas, attitudes and ways of reasoning acquired out-of-school before instruction were strong and quite resistant to change by instruction. These results provoked us to look more precisely to the problems causing this lack of success in reaching our aims of learning.

4. Problems of teaching radioactivity in a risk perspective

As we assumed the issue of how to teach ionizing radiation in a risk perspective more effectively to be rather complex we used a variety of research methods, such as the consultation of radiation experts in a Delphi-study on the issue, the analysis of newspapers, the analysis of scientific literature and school textbooks, interviews and questionnaires with pupils, interviews with teachers, and observation of lessons.

As time is limited I will only sketch some of the main problems which we investigated or detected in these studies. For more details I have to refer to papers presented yesterday by Piet Lijnse and myself in the workshops, and to other english articles about our work (Eijkelhof et al., 1987; Eijkelhof and Millar, 1988; Lijnse et al., in press). We hope to publish more of our results in a forthcoming dissertation.

A. the complexity of risk assessment

From the risk literature we learned that risk assessment is a rather wide concept. Three important components could be distinguished (Rowe, 1988):

(i) risk identification: this includes identification of causative events, observation and recognition of new risk parameters, the recognition of new relationships among existing risk parameters and perception of change in the magnitude of these parameters
(ii) risk estimation: this encompasses the determination of the magnitude of consequences and of the probabilities of outcomes
(iii) risk evaluation: the developing of acceptable levels of risk to individuals or society; this includes weighing risks and benefits, determination of acceptability levels below which the risk is accepted and above which aversive action is seen as required.

Such an approach of risk assessment is quite different from the way lay-people are used to approach risks (Covello, 1984). In order to be able to assess the risks of ionizing radiation in a more expert-like manner one has to be familiar with a large number of scientific concepts and processes, risk parameters, benefits, ways of reducing risks, alternative approaches to the same ends, weighing procedures etc. Obviously we could not make our pupils full experts. So choices have to be made. Which aspects of risk assessment should be included in education and which ones left out? Some will be more useful than others. But what is useful? Another point is that especially the third aspect - risk evaluation - involves values. What is acceptable? Which criteria are presented as relevant for acceptability? The answer on these questions strongly depend on one's aim of including risk aspects into the curriculum. We will return to this point a little later.

B. suitable contents and contexts

Once the general aim of learning to assess risks of ionizing radiation has been chosen, the question arises which scientific contents and contexts would be suitable. As is common among curriculum developers the contents and contexts of the PLON-unit were chosen rather intuitively, with the danger that important concepts and contexts are missing, or that non relevant ones are included. Because of the facts that ionizing radiation is involved in many spheres of life and work and that some controversial aspects are involved in risk assessment, we have the opinion that some form of legitimation of the curriculum is required from experts in the field (Eijkelhof and Lijnse, 1988).

Therefore we carried out a Delphi-study of three rounds among about 50 radiation experts. Some of the results are:

* more attention in physics education should be paid to basic knowledge about radiation protection: dose concepts, effects of ionizing radiation and safety aspects

* more attention should be paid to contamination with radioactive substances: present physics education is mainly dealing with closed sources; open sources constitute an important and from protection viewpoint different problem

* contexts should cover a large part of the collective dose, most important social implications and a variety of applications: the

recommended set contexts consisted of 'background radiation', 'medical applications', 'emission of radioactive substances by nuclear power stations', 'storage of nuclear waste', 'fall-out of nuclear arms explosions', and 'some current industrial applications'

Although the views on applications of ionizing radiation were very different, the above mentioned conclusions were rather unanimous. Far less agreement existed among the experts on the usefulness of risk comparisons for education. A great number of objections of a different nature were ventilated.

C. pupils' preconceptions

We found that a number of lay-ideas about ionizing radiation exist which obstruct a thoughtful assessment of risks involved. These lay-ideas were often found in newspapers and in interviews with pupils, so it is likely that these ideas are for a large part socially acquired (Solomon, 1987). Some of these lay-ideas we also found among many 6th formers who received physics education on this topic, either by the PLON-unit or by traditional methods. So they are also rather persistent. Which were these lay-ideas?

a. endurance of radiation: "when radiation falls upon an object or a living body or is released into the air, it does not disappear, at least not completely; therefore radiation could accumulate in an object and in the air"; this idea might be due to a more general view that dangerous things never disappear completely and could only be diluted, e.g. chemical solid and liquid waste, air pollution; from a scientific point of view one might conclude that they lack the idea of 'absorption of radiation'

b. contamination is the same as irradiation: "when someone or something receives radiation one might call this person or this object 'contaminated'"; this probably relates to the previous preconception; from a scientific point of view one might add that no distinction is made between 'radiation' and 'radioactive matter'.

How serious are these lay-ideas? We may illustrate the implications of these lay-ideas for daily life by referring to some practical examples experienced by radiation experts and ventilated in the Delphi-study:

- reluctance with the public to buy irradiated food for fear of radiation
- during the demolition of hospital buildings some politicians had the idea that walls of a medical X-ray department are full of radiation and therefore should be treated as radioactive waste
- some workers who look after animals which are irradiated by X rays in experimental settings had a feeling of being neglected: they had not been issued dosemeters and did not get regular blood tests in contrast to personnel who irradiated the animals, although the latter personnel had less contact with the animals
- an industrial worker who received an extra radiation dose by accident got socially isolated: he was considered by his neighbours and co-workers to be suffering from 'radioactive contamination' and therefore dangerous.

Our conclusion is that a number of lay-ideas seem to be resistant to change in present physics education, including the PLON-course, and that these ideas interfere with our aim of risk assessment. So educational strategies should be devised to deal with these lay-ideas.

D. pupils' attitudes towards the risks of ionizing radiation

Pupils do not live in a social vacuum. Long before we teach them about radioactivity and ionizing radiation they will have been informed about risks of ionizing radiation and have developed a certain attitude towards these risks. As is common with all attitudes: they resist change. New information is interpreted mainly in such a way that it fits with the existing attitude. Disconfirming information then is seen as unreliable, erroneous and unrepresentative.

For instance, it is reported in the literature that convincing people that a hazard they fear is safe is extremely difficult, even under the best conditions. This is attributed to a defence of self-esteem which requires stability and consistency (Sjöberg, 1979) and to the intertwinement of beliefs about risks in a complex system of beliefs and values, shaped by the social system, the world view and the ideological premises of a group or society (Douglas and Wildavsky, 1983).

Among pupils we detected two polar kinds of attitudes:

a. **radiation is always dangerous**
Pupils who have this attitude tend to reason that radiation is permanent and would never disappear completely; in their view all kinds and all amounts of radiation are dangerous and therefore radiation standards have a limited value

b. **the risks of radiation are limited**
Pupils having this attitude tend to reason that radiation decreases and could drop below a safety level; in their view small amounts of radiation (especially X rays) are not dangerous at all and could be broken down by the human body; therefore standard levels indicate that it is safe below these levels

Let me give you some examples of how these attitudes work. Regarding safety measures, the first group of pupils will argue: look at these safety measures, the stuff must be really dangerous, so we are at risk; the others would argue: look at these safety measures: we are well cared for and so we will be really safe. After an incident in a nuclear power station the first group would say: this really shows how risky nuclear power is; the second group would say: the damage was only limited so a nuclear power station could be kept under control.

One may expect that pupils with attitude a ('radiation is always dangerous') tend to resist more to assimilate scientific information than those having attitude b ('the risks of radiation are limited'), as scientific information is often used to delineate risks.

Another relevance for education may be that a teacher should recognize that various views about the risks of radiation exist in class. These views are likely not to be superficial but are based on some attitudes towards risks in general, possibly reinforced by certain preconceptions and by reports in the media. Such differences of attitude could be an asset in class discussions about radiation risks, but could also have a negative impact on those discussions if not well managed.

E. teachers are not very familiar with the above mentioned problems

From our interviews with teachers and from our analysis of existing school textbooks we may conclude that teachers are not very familiar with the dose-effect side of ionizing radiation, with safety regulations, with methods of risk assessment, with pupils' preconceptions of ionizing radiation and with the factors which influence the strength of existing beliefs and the attitudes on which the beliefs are based. Some teachers seem to have the idea that presenting the correct scientific facts and principles would be sufficient for learning. Our studies show that there are good reasons to have doubts about this belief. Some insight in the problems mentioned above seems to be necessary for teachers in order to be able to teach effectively about radioactivity and risk. This requires attention in pre- and in-service training of teachers.

5. Aims of teaching about radioactivity and risk

Especially from our Delphi-study among radiation experts we have learned that teaching about radioactivity and risk could be done with a variety of ends in mind. These ends are value-laden, although these values remain often hidden. We may distinguish the following five ends of teaching ionizing radiation in a risk perspective:

(i) pupils should have a more positive attitude towards radioactivity
(ii) pupils should be more aware of the potential hazards of all quantities of ionizing radiation
(iii) pupils should know when and how to be careful with radioactive sources and ionizing radiation
(iv) pupils should be able to appreciate the effectiveness and limitations of radiation safety measures
(v) pupils should be able to make decisions in matters of personal and social relevance related to the risks of ionizing radiation.

In my view it should not be the aim of education to change attitudes towards ionizing radiation in a particular direction, as is implied in the first and second ends. Attitudes should be developed by pupils themselves and, except perhaps in matters of human rights, not be imposed upon them by their teachers. This does not mean that education should just reinforce existing attitudes. I would be in favour of opening the possibility for changing attitudes, for instance by widening the scope of pupils: showing which aspects should be taken into account, making distinctions where appropriate.
As final aim I would prefer the fifth one, although I realize that this is not an aim which could be fulfilled in the usual number of teaching periods as this is the most complex one.
It may be more realistic to aim at the third and fourth ends, as they are quite close to the initial interests of pupils and could be seen as prerequisites to the final end.

6. Recommendations for curriculum development and research

What lessons could be learned from our work on teaching ionizing radiation in a risk perspective for curriculum development and research?

The first lesson is that risk assessment is very complicated and aiming for this in education requires choices regarding the ends and objectives. In our view the ends should be made explicit and too complicated objectives, for instance those requiring a lot of very specific knowledge, should be avoided. Examples are analyzing the risks of failure in nuclear installations and making risk comparisons with other risks in daily life.

The second lesson is that some new concepts and contexts should be included in the curricula, especially those regarding radiation protection. More attention should be paid to the dispersal of radioactive substances, ending the tradition in physics education to focus on closed sources.

The third lesson is that preconceptions and attitudes towards the risks of ionizing radiation seem to play a major role in learning. How to take these best into account is a question which requires a great deal of further research, some of which we are carrying out at present, for instance by revising the original PLON-unit and evaluating its learning effects.

Our fourth lesson is that teachers should be better prepared to teach ionizing radiation from a risk perspective. In pre- and in-service training special attention should be paid to pupils' preconceptions and initial ways of reasoning about risks of ionizing radiation, and to scientific risk and safety aspects of ionizing radiation.

A final lesson is of a more general nature, not restricted to our topic area but important enough to be emphasized here. This lesson is the opinions of teachers and pupils are not always a reliable measure for effective learning. Some problems are not noted from the position of the practitioners, who seem to judge mainly on the basis of how a unit is appreciated by the pupils, how it 'works' in class and how pupils respond to the test questions set by the teachers. So in assessing the effectiveness of a unit one should not go by very positive comments of teachers and pupils alone: those deserve a critical approach.

Are we discouraged by the research findings so far? I tend to say no. I still believe the same reasons for teaching this topic in a risk perspective are valid: it suits the interests of pupils and it has potential value beyond preparation for further studies, as we may expect that pupils nolens volens may encounter ionizing radiation in their personal and social life during the next decades. We have only learned that teaching so is not without any problems. I do believe that many of these problems will be solved in future in cooperation between teachers, curriculum developers and researchers. I hope some of you will contribute to this.

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RISK PERCEPTION STUDIES IN SCHOOL

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In this talk I shall try to make the case that this is not a subject which just depends upon learning "sound physical principles", "learning to think like a physicist", or even "taking all the evidence into account". Risk perception may require quite different approaches and different ways of thinking to those we usually use in physics lessons. Should we be unwise enough not to learn from the literature and research into the public understanding of science, media studies, and social psychology, our efforts may do more harm than good. To insist that the physicist's way of thinking is the only one, for considering the social effects of science, damages rather than enhances the pupils' image of science. As John Ziman (1980) wrote

> "It reinforces, without question or comment, the widespread sentiment that science should be the only authority for belief and the only criterion for action" (Ziman p[illegible])

Public Understanding of science

The DISS project (Discussion of Issues in School Science) has been funded as a part of the linked research programme which is exploring the British public's understanding of science. It is a subject which has recently attracted a great deal of attention. As David Layton (1984) has pointed out it is often not the designs of the curriculum developers, nor those of the educational researchers, which set the agenda for large-scale educational change. Certainly we in Britain have had cause to learn this lesson in a very profound way during the last two years. No one could claim that our new National Curriculum is firmly based on either the enlightened principles of the Nuffield Physics scheme nor upon the ample body of educational research which has demonstrated the dire effects of labelling children as "less than average ability" early in their schooling. This is an example of

> "macro-level influences from the national cultural context on outcome of events at the classroom level." (Layton 1984 p22)

Interest in the public understanding of science is probably just such an outcome of national and indeed international concern about environmental problems, coupled with a continual worry about our industrial prowess. In July 1989, in the aftermath of the Green Party's successes in the elections to the European Parliament the then Secretary of State for the Environment attacked this new political force with arguments about "mis-information" and promises to set up a governmental agency to hand out guaranteed scientific "facts" about the environment.

But are facts enough? The Royal Society report on The Public Understanding of Science (1985) began with the assertion that some undertanding of the methods of science were also needed.

> "..Understanding includes not just the facts of science, but also the method and its limitations as well as an appreciation of the practical and social implications." (6.6)

Less attention was given to either public attitudes towards science, or private values. In an article explaining the Royal

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Society's report Collins and Bodmer (1986) wrote that "an individual needs some understanding of science to feel at home with the findings of science" (p97), as though understanding were a prerequisite for feeling and so, perhaps, for attitude. They concluded that the most difficult task for future research would be measuring understanding - a task considered to be distinct from, as well as more important than, the measurement of attitudes.

Of course it is not possible to provide a formula for understanding in which we add facts, to knowledge about processes, and then season it with suitably favourable attitudes. What the public **can do with scientific information** is sometimes referred to as "scientific literacy". Miller (1983) separated this into "being learned" about science, and being "literate" in science. The first of these comprises scientific knowledge whereas the second

> ".. refers to the ability of the individual to read about, comprehend, and express an opinion on scientific matters"
> (Miller op cit. p 30.)

It is this aspect of scientific understanding which forms the basis for citizen decisions about personal or national risk.

There have been surprisingly few measurements of the public's scientific knowledge. A recent short questionnaire study by Lucas (1988) recorded scores which were not impressive The questions included wiring a household plug, the effect of altitude on the boiling point, the relative speed of light and sound, and, predictably, radioactivity and nuclear wastes. It was instructive to note that the question about the tides, perhaps the most esoteric, was the best answered - better even than the wiring of the household plug - and that the question on radioactive waste met with least success.

Although success rates on questions with different wording, and hence different types of ambiguity, defy real comparison, the immediate impression is that in areas of risk there is less "knowledge" and not, as we might have supposed, more. Lucas carefully avoided the pitfall of bemoaning the inability of those who failed to answer these questions correctly to make their own decisions about issues. The survey questions, he insisted, were about understanding for its own sake and the results demonstrated a kind of cultural deficiency.

A more ambitious survey trying to assess interests, attitudes, and knowledge has just been completed (Durant et al 1989). As often in such studies self-reported interest proved greater than self-reported knowledge even by the most interested sections of the public, a result which might be explained by a greater appreciation of the extent of possible knowledge. Other results showed a poor grasp of factual knowledge which was, however, higher for those with more recent schooling, and correlated well with final educational level. One of the reasons these authors gave for caring about the public's understanding of science is that "science affects everyone's lives". But where an issue very closely affects a person, Lucas' results as well as our own insights, show that this assumption of cool understanding based upon knowledge of content and process becomes less convincing.

Ravetz (1971) adopted the opposite approach to understanding which set the individual's scientific knowledge in the domain of his/her own personal attitudes, values, and concerns. This was a radical departure since it no longer accepted the given-ness of scientific knowledge and its correct understanding. Ravetz wrote of folk-science as a reconstruction of science which loomed large in people's thought because it affected their lives and their world-picture. We and our pupils all reconstruct the knowledge that we receive - even the physics knowledge - in order to fit it into our way of thinking. But where we feel that we, or those we love, might be in danger the reconstruction can be more substantial. Our motivation is no longer an armchair interest in the culture of physics but a more urgent need to trust in a system which may be able to give comfort in the face of threat. What we make out of the information we receive then becomes our very own "folk science".

Even in 1986 when Layton, Davey and Jenkins explored recent research into the specific purposes for which people use scientific knowledge, they could point only to studies of people's understanding of energy consumption in their homes, or of colds, infections and remedies, as illustrations of their reconstruction of the scientific knowledge which affects their habitual way of living.

Since that time there have been studies on several special groups' understandings of aspects of scientific risk - about Cumbrian sheep farmers and the precautions about radiation hazards relayed to them by MAFF scientists (Wynne 1987), and about residents living near Selafield and the making of a television programme on radioactive pollution released from the plant (Macgill 1987). Both studies come into the area of risk perception where there can be no divide between understanding and interest.

The Acceptability of Risk

In her important study of risk perception Mary Douglas (1986) explored three different perspectives on risk:-

(a) The "engineering approach"

This assumes that all we need to know are the "facts". These will include numerical probablities of risks of death or injury, and their numerical tolerances. In more complex situations (which life so often provides) comparisons between the risks inherent in alternative courses of action can be calculated by adding the risks, with appropriate weightings, and subtracting the benefits, in a cost-benefit analysis (CBA).

The report on the The Public Understanding of Science laid particular emphasis on a suspected lack of understanding of probability when expressed as "a one in three chance of....", and yet the survey quoted above (Durant et all op cit) could find no such prevalent misunderstanding when the question was set in a formal and non-threatening situation. Yet the public still remains sensibly unconvinced by cost/benefit statements of the kind "the annual risk of living near a nuclear power station is the same as driving an extra 3 miles a year in a car." Risks appear to be of quite different severity to different people.

Fig 1. The Personal Acceptability of Risk

More?	Acceptable	Less?
Own action		Action of others
Effect can be treated		Effect always fatal
Effect felt immediately		Long delayed effect
Gain makes it worthwhile		No possible gain
No alternative		Many alternatives
Less risk with skilled use		Skill of no effect
Used as intended		Used in a new way
Consequences reversible by stopping		Quite irreversible
Risk well understood		Risk mysterious
Voluntary with others		Inevitable at work

(In the light of suggestions in this table the equation between living near a power station and driving a car becomes less convincing. Can one live "skilfully" near a power station? Does one know, even, if there has been any damage? Is it reversible?)

CBA is obviously essential for many purposes within industrial management, but there has been very grave doubt how far it can be used in public decision-making about risks. When the Third London Airport Inquiry was going on in the 1970'3 such factors as the nesting sites of migratory birds, the value of a ruined Norman church and the disturbed sleep of residents had all to be given a figure. Only then could they be entered into the balance sheets of CBA.

(b) "The ecological approach."
In this kind of risk perception hazards are sorted out into their perceived characteristics. As in plant ecology it is assumed that the subjects will react to hazards differentially and try to adapt to them. It becomes the individual's ability to cope with a hazard which is the a measure of their acceptability of risk. But where adaptation is the only resort of a plant in a hostile environment, human societies have other solutions.

(c) "The social justice approach"
This moves away from the locus of the individual to the society and citizen choice. It may not turn on formal calculus or logic, but it is not irrational: it will hear a call for social justice, or for some strategem which will mitigate the social "unfairness" of risk. In our everyday lives this third path is an active and common one; when a family or a street is threatened we neither make calculations of probability, nor are we endlessly content with just coping with the problem. We allow ourselves to use indignation and empathy in a rational reaction which tries to ensure that this cannot again cause such distress.

Science on Television
Several studies have shown that both adults and older children

attribute a great deal of their science knowledge about all environmental issues to television (review by Wiesenmayer et al 1984). Video excerpts were used in the DISS project as the trigger for discussion in much the same way as they might be in everyday life.

Television's images affect thinking in special ways. They do not invite counter-imagining, as radio or a book might do, so any group of people who have just watched a programme on risk, share a common network of pictures. In their detailed study of children talking about television programmes Hodge and Tripp (1986) concluded that visual images were used to "concretise" a narrative. This was then followed by much talking over of the programme in which the children shared impressions of the images they had just seen. In the DISS project, too, we have found long passages of similar talk as the students share their experiences of images of risk.

In his authoritative review of television research McQuail (1984) concluded:

> "There is a growing body of opinion and a good deal of evidence that the effects of mass media are much more to be found in the provision of what Lippmann called 'the pictures in our heads', the frames of reference and the cognitive detail about the world." McQuail p13

McQuail goes on to speak of "definitions of the situation" in the same context.

These views on the agenda-setting power of television imagery suggests that it may be essential scene-setting for the "framing" process of which Minski wrote. He defined a "frame" as a collection of questions to be asked, issues to be raised and methods to be used in the analysis of an issue (1975).

Another characteristic of television is the "para-social interaction" that it sets up with the viewer. This not only explains the popularity of "soap-operas", it also adds a social element to the knowledge content of programmes about science-based risks. In the DISS project transcripts we have found a considerable amount of caricaturing of the presenter which has affected the students' reception of the knowledge or perspective that he/she was giving.

School science and perception of risk

There have been only two substantial studies of school students' perceptions of risk. Eikelhof (1985) reported on the responses of Dutch students who were studying course elements on ionising radiation in a mainstream school physics course. He reported that misconceptions "seem to emerge when students are forced to use their school knowledge in real-life situations".

The other study, Solomon 1985, was of students talking and writing about the future of energy resources during a middle school physics course. The findings indicated the same reluctance to use school knowledge in a real-life context. It was also shown that girls' evaluations were more social and judgmental in nature than were those of the boys.

In an interview study of Canadian students Fleming (1986) found more indications of this Two Domain effect. Students regularly used social knowledge and even spurned the offer of scientific information. They "focussed on the people doing the science rather than on the products of that work". Aikenhead developed a very carefully validated multiple choice instrument for collecting students views on the risks associated with Science and Technology. He confirmed (Aikenhead 1989) the difficulty that 17 year old students commonly have in answering questions about scientific knowledge. Both studies confirm that expressing an opinion on some scientific issue does indeed require some understanding of the nature of scientific knowledge and dispute.

Talking in small groups

Research in the USA (Weisenmeyer et al. op cit) has shown that "high interactors" claim to acquire most of their knowledge about environmental issues by this method. When people are unsure of the information they have received they are more likely to talk it over with their friends, whom they trust, even though they may be just as uninformed as them, than to write to unknown experts for explanations. The reason is not just a distrust of experts whom they do not know, but a need to get clearer what the issues are, by a process of verbal and social reconstruction.

It is only recently that the value of group talk in science has been appreciated. The 1983 JMB syllabus for Science Technology and Society was probably the first to include this as an obligatory part of its internal assessment (Solomon 1989). The students who took part in the DISS project were all taking this course.

Small group discussion of controversial issues, between friends and without a teacher, has certain very valuable features. It allows the process of scene-setting or framing to proceed naturally, it encourages the shy and timid to contribute, and it permits a sharing of perspectives on risk which may usefully mirror those in society at large. Only when this empathic process is completed can adequate social strategies be suggested and discussed by the participants. The process was explored theoretically by Bridges (1979) as follows (my paraphrasing)

- being a goal in itself (each participant working out their own value position)
- leading to understanding a variety of responses
- a basis for choice between value positions
- a basis for a social strategy to resolve the issue.

Results from public understanding show the inevitability of reconstruction of issues in a social setting. Media studies literature has contributed ideas about scenes and frames for understanding risk, and both physicists and educational researchers warn that an exclusively scientific stance damages the image of science that non-scientists hold. For all these reasons the discussion of risk in small friendship groups seems a method well worth using.

The students in the DISS project have produced most interesting material which we are still analysing. It is clear that they

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enjoyed the sessions and made full use of them. They spoke about science and scientists. They often identified important areas where they said there should be "more research". But when they were trying to engage with their friends in working out value positions, or trying to suggest a possible solution, they would place the problem in a more homely setting. They moved away from the universal to the particular, just as Socrates did in his ethical probings, and asked - "What would you do if it was your Mum?" In this way they went some way towards using the full range of their cognitive powers - scientific, empathic and ethical - as any citizen must do in the face of personal or national risk. It also seems to represent an important step towards the goal of truely holistic education.

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SOCIAL AWARENESS OF NUCLEAR RISKS

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Extremadura is a region in the west of Spain whose principal activities are agriculture and livestock, and which possesses, in addition to several hydroelectric power stations, two nuclear power stations: one in Almaraz (fully operating) and another in Valdecaballeros (under construction). The social awareness of the risks which the utilization of Nuclear Energy involves is rather poor, even among the science students in the first years of their degree courses: what is worse, the facts are distorted by a frequently sensationalist press and by the often exultant tone of the informative leaflets from the Nuclear Power Stations themselves. Research carried out by the Physics Department of the University of Extremadura could remedy this lack of awareness by acting appropriately in two ways:

a) by including in the study programs of the first years of Science Degree courses one or two lectures, or several seminars, which would deal accurately with the possible risks of Nuclear Energy and collect all significant date provided by the Physics Department research on the subject, and

b) by publishing in the local press the results of the investigation in accessible language.

SCIENCE IN SOCIETY COURSES AND UNITS AT THE TORONTO BOARD OF SCHOOLS

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The topic of the impact on society made by scientific discovery, and by the accelerated development of technology has been addressed in several of the science courses taught in the Secondary level in the Province of Ontario. Those courses came about because of individual teachers' efforts and interests, with no support from any organization, yet teachers could find relevant material through the media department at the board of education, and organizations as Ontario Hydro, the province's Electric Company which supplies data, pamphlets, and speakers about the different energy resources, particularly on atomic sources and the Candu reactors. Although teacher's interest remains a crucial factor in the success of this courses, it is now recognized and emphasized in philosophy of the guidelines of the new curriculum.

NEW RESPONSE:

The whole issue is now taken more seriously as mandated by the Ministry's new curriculum, in tune with the recommendation of an independent committee at the Toronto Board of Education,

An outcome has been the introduction in the Secondary Guidelines of a recomendation to address the impact of science and technology in all science courses. (there are fifteen science courses in the Advanced University bound Level)
This can be achieved by teaching a separate unit, and/or having a discussion in pertinent parts of the curriculum, with evaluated projects the students have to research, ranging from the effects of acid rain in a particular lake, to computerized identification of missing children.

This Policy appears in the Program Outline and Policy of the Science Curriculum Guideline.

POLICY:

> "The curriculum outlined in this science guideline places distinct emphasis on the science--technology-society connection. For this reason scientific applications and societal implications are mandatory components of each unit of study. In addition, Part 1 of the guideline underlines the need to incorporate morals/values education into science courses. Undoubtedly, this will give rise to the discussion of some sensitive issues.
> Such discussions are important. Generally, they should be focused and should provide an open forum for the expression of different viewpoints. In this regard teachers of science are urged to familiarize themselves with section 10:"Values in Science Education", and to pay particular attention to the principles to be observed when dealing with sensitive issues in the science curriculum. (Appendix I)

At the Toronto Board of Education an ad hoc group, the "Thinking and Deciding in a Nuclear Age Advisory Committee" had been meeting to discuss how this topics should be taught. One of their outcomes is the production of a teacher's resource book and support material for teachers who want to explore teaching a unit in a science course, that will explore the following topics:

What is Technology
What is Work
Technology and Work
Technology and Values
The Economic Order
The International Economic Order

The support material provides extensive bibliography, included that of videos and films; evaluation suggestions. Also it offers particularly useful description of interactive activities with the students, ranging from putting the caption to provocative cartoons, to envolved group activities and discussions. It provides suggested forms of evaluation. (See Appendix II)

A new course, on Science and Society, focusing on the impact of the accelerated development of science and technology on our society, has been planned to be offered starting this week, throughout several schools in the Province of Ontario, at pre University Level: Universities entrance requirement are a minimum of six Ontario Academic Credits. English has to be one of them, three or four of them are pre-requisites for the career selected by the individual student, leaving some degree of freedom for the two or three of those pre-university credits left, from a menu of about eighteen different courses. Science in Society will be one of those options in several of our province's school this year. The Ministry of Education has provided curriculum guidelines, and placed pre-requisites, the Board's of Education provide documentation, and video resources, yet in an initial form. (For Guidlines see Appendix III).

There is a grade 12 Environmental Science course. It's goal is to educateand sensitize students in the urgency for the care and change of atititude of all people, and naturally the governments on the care of our planet. (See Curriculum Guideline, Appendix IV)
It has been particularly successful when students went out to the field and actually worked in clean-ups, testing the composition of the waters of the city's Rivers, or in programs of reforestation, or in Toxic Waste Management Plants.
The number of hours worked, and the aknowledgement of the work done varied from credit for the course, to hourly paid work. A new possiblity in that area are the Co-op courses now incorporated to our curriculum:

CO-OP:

Students must obtain one credit in an area at their school, and they can then add another as 2 more credits in the same area, by doing 120 hours of work for an industry, or other work place. Teachers monitor and evaluate the field work in conjunction with their students field supervisor.

This puts students directly in contact with the work situation today, allowing a fruitful learning of the the status of work and more in depth discussion on the future of the workplace

IN THE PAST

At least 3 other different courses have been taught in Secondary Schools, of different flavours and emphasis, depending who, where and why they were taught. One of them was offered at City School in 1987. It was an interdisciplinary course on the impact of technology on society. The interdisciplinary aspect is part of the school's individual specialty, where each year a course of that nature is offered, by a group of teachers, to students of all grades together. The organization of the course is shared with some of the students to make the course rooted in their interest. The course included research done in groups, a visit to industries with a pre-checked questionnaire, and several experts visits to the school: new technology users, union leaders, researchers in genetic engineering, librarians, and professors. Students had to write a report on each visit and a discussion followed.

CONTENT:

History of work, labour, and unions
Trends
Industrial Revolution
Comparison with todays "Automation Revolution
Visit to Industries and Interviews
The Future of Work, impact of technology
Science
Values and Policy

The overall result of the course was somewhat less enthusiastic than other interdisciplinary ones (like UN with mock assemblies, or a course on the sixties).
One of the reasons was that the discussion and prediction for the future looked dim to our students. Particularly depressing to them seemed the continuous deskilling produced by renovated and accelerated mechanization and automation, which reduces the number of jobs, and transforms those left into supervising or being slave to a machine. Interesting and challenging jobs appear too, but much less of those will be needed. The mechanization of work in the service sector is scary to many of our students who are currently earning their pocket money there, or in the dissapearing primary sector. The lack of options for the majority of the population for interesting jobs, for enduring occupations. The shift towards service work in the occupations, and the mechanization of human labour were clear and threatening. The course was worthwhile, interdisciplinary, but it was not an encouraging look into the future of work. An aspect I would want to be able to honestly incorporate in the teaching of the Science and Society course.

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Handling Sensitive Issues

Issues by definition involve differences of opinion, which sometimes involve deeply held viewpoints and beliefs, religious and otherwise. The following principles are to be observed when sensitive issues are dealt with in the science curriculum:

1. School boards are to ensure that instruction related to sensitive issues in science is treated in a sensitive and scientific manner. Care should be taken to introduce such issues only at times when the maturity level of students is appropriate. The premature treatment of an issue must be avoided.

2. When dealing with any theory in the classroom, the teacher is expected to discuss the strengths, limitations, and tentative nature of the theory with students. Students should be given ample opportunity to consider the processes and the data gathering on which such a theory depends. When examining the validity or acceptability of a theory, the teacher is to stress the importance of the theory as an explanatory device that is intended to correlate with observed phenomena.

3. It is not the intention of the Ministry of Education explicitly to include or exclude all viewpoints or explanations of any given phenomenon or process mentioned in the science curriculum. Generally, the most widely accepted viewpoint is required in the program, but this must not be interpreted as implying that other perspectives are not valid or are not to be presented or discussed. In fact, the introduction of two opposing views often heightens the interest of students and results in a more open-ended and discerning approach to an issue-oriented topic.

4. The science staff within a school, in consultation with the principal, should decide which issues of relevance and concern to students and society will be emphasized. Community concerns related to such issues must be taken into consideration in the design of specific courses. There should be a sound rationale for deliberately including a sensitive issue in the program.

5. Some issues will be introduced through curriculum design, others, through the spontaneous initiative or curiosity of a student. In either case, the teacher shall ensure a sensitive and rational treatment of the issue and act as a role model in an environment of mutual respect. The teacher should assist students to:

   a) develop, articulate, and reflect on their own points of view
   b) listen to and consider the views of others
   c) try to understand and appreciate both sides of an argument
   d) take into account relevant information
   e) consider various interpretations of collected data or observed phenomena
   f) appreciate the possible ethical, cultural, racial, national, or religious implications of a point of view
   g) grow intellectually

(APPENDIX 1.)

6. The background information that is provided about any sensitive issue should

   present various scientific points of view in a way that minimizes prejudice
   b) reflect students' interests, needs, capabilities, and level of maturity
   c) reflect community concerns as well as provincial, national, and international implications
   d) reflect complementary or divergent perspectives that may be held by people with different cultural, racial, national, or religious backgrounds
   e) relate to Ministry of Education curriculum-guideline requirements

7. In science classes different viewpoints, including those based on deeply held religious or cultural beliefs, should be presented and discussed in a respectful and intelligent manner. If an issue in the science curriculum relates to religious perspectives, the teacher and students must understand that in the science classroom other realms of knowledge, such as religion with its doctrines and faith orientation, must be respected for their own intrinsic value and contributions. However, just as religious education by its nature must involve students in the study of religious knowledge and methodology, science education must involve students in the study of scientific knowledge and methodology. Students of all backgrounds should be encouraged to view science education as an opportunity to learn about the scientific viewpoint. If the material being studied in a particular unit is likely to be incompatible with the deeply held religious beliefs of some students and their parents, then such material should be treated sensitively and with discretion. In some situations it may be appropriate to assign alternative material to the students concerned.

8. When evaluating student achievement in a topic that is sensitive or controversial, the teacher must take care to observe the following guidelines:

   a) Students may be asked to outline or describe a scientific theory or view even though they may not believe in it. They should be informed that their answers will not imply their *belief* but serve as an indication of their *knowledge*.
   b) If students are asked to outline or describe their beliefs or opinions about an issue, then the evaluation must be based on purely objective features such as organization, reasoning, sequence, development, readability, and overall presentation, not on the actual belief or opinion, particularly if it is divergent from that of the teacher.
   c) Students are to be informed in advance of a test or examination of the criteria that will be used in the evaluation process, particularly when a question deals with a sensitive or controversial issue.

APPENDIX II.

TO THE TEACHER: AN INTRODUCTION

- 1.1 How To Use This Curriculum
  - 1.1.1 The Curriculum - Unit by Unit
  - 1.1.2 Timelines for Using the Unites
- 1.2 Curriculum Objectives and Evaluation
  - 1.2.1 Knowledge Objectives
  - 1.2.2 Skills Objectives
  - 1.2.3 Attitude Objectives
  - 1.2.4 Evaluation
- 1.3 Resources
  - 1.3.1 The Resource Section
  - 1.3.2 Special Resource Activity: Using Maps
  - 1.3.3 Special Resource Activities: The Difference between Arguing and Discussing

UNIT 1: WHAT IS TECHNOLOGY

- Topic 1.1 How Technology Is Used
- Topic 1.2 The Development of Technology
- Topic 1.3 What Is Technology
- Topic 1.4 Issues for Modern Technology

UNIT 2: WHAT IS WORK

- Topic 2.1 From Technology to Work
- Topic 2.2 Where People Work
- Topic 2.3 What Is Work Worth?
- Topic 2.4 What Is Work?

UNIT 3: TECHNOLOGY AND WORK

- Topic 3.1 The Changing Workforce
- Topic 3.2 The Changing Workplace
- Topic 3.3 Working with Changing Technology

UNIT 4: TECHNOLOGY AND VALUES

- Topic 4.1 Who's in Charge Here?
- Topic 4.2 Issues in Coping with the Changing World of Work
- Topic 4.3 The Value and Purpose of Technology

UNIT 5: THE ECONOMIC ORDER

- Topic 5.1 From Work and Technology to Economics
- Topic 5.2 The Family as an Economic Unit
- Tovic 5.3 Economics and the Nation State
- Topic 5.4 The World Economic Order
- Topic 5.5 What is Economics?

UNIT 6: THE INTERNATIONAL

- Topic 6.1 Problems Facing World Society Today
- Topic 6.2 Issues in International Economics

Particular Features of Science in Society, OAC

(APPENDIX 3)

Units of Study and Their Time Allocations

The following chart provides an overview of the units of study in Science in Society, OAC. It also indicates the time to be allotted to each unit.

Science in Society, OAC (SSOOA)

Units of Study	Time Allocations
Core	
1 The Nature of Science	20 h
2 The Nature of Technology	20 h
3 Humans in the Environment	20 h
4 Current Issues in Science	30 h
	90 h
Optional	
Locally Designed Unit	20 h
	110 h

If a local unit is not done, no more than seven hours should be added to each core unit.

The Purpose of Science in Society, OAC

Science in Society is a course for both avid science students and students who have an interest in science as it affects society. Science-oriented students will increase their knowledge of aspects of science that are not normally emphasized in courses that are focused on individual science disciplines. Such aspects include the contribution and responsibility of science and scientists to society; the influences of societal forces such as economics, values, and politics on scientific research; and the historical development of modern scientific knowledge. In addition, since this course is an interdisciplinary approach to science, science-oriented students will be exposed to an integrated perspective on science.

Students not specializing in science will, in addition to the above, increase their understanding of science, its methods, and its knowledge, which will assist them in becoming informed problem solvers and decision makers. They will also learn something about the role of science and technology in society.

This course is essentially concerned with developing concepts through experimentation, discussion, research, critical thinking, and analysis; it is not designed primarily to instil a specific body of knowledge. Roughly speaking, the course should deal with scientific content and processes for about 70 per cent of the time and with related societal concerns for the remaining 30 per cent. Each student should be encouraged to discuss and reflect on his/her experience and viewpoint regarding the role of science and technology in the varied aspects of society, past and present.

The emphasis in this course is designed to produce students who are well versed in the issues surrounding science and technology and are able to analyse them critically. The course will provide students with the opportunity to develop introductory research skills involving a wide range of materials and enable them to report and defend their findings in both oral and written form. They will also develop a historical perspective that should allow them to compare present trends and attitudes with those from the past, and they will be encouraged to develop their ideas about the future impact of science on society.

Since there are many different viewpoints and opinions on any specific issue, students should be encouraged to be sensitive to the values and views of others whenever they are proposing solutions to problems. A major aim of the course is to increase understanding of the complex issues facing our society among a broad range of students, who will be our future lawyers, business people, politicians, educators, and citizens.

ACID RAIN MONITORING IN SCHOOLS

Ildikó Hobinka, Miklós Riedel, Balázs Jávorszky
Fazekas Gammar School - Dept.Phys. Chemistry, Eötvös University
Budapest, Hungary

One of the risks of the fossile energy production is the acid rain. Acidic deposition has become serious ecological problem all over the world. The most important products of the combustion of fossil fuels are CO_2, SO_2 and NO_x. The amount of N_2 fixed per year by energy production is estimated of about $1.3 \cdot 10^{12}$ moles. The ratio of $SO_2:NO_x$ emission lies between 1:1 and 3:1. The acidity of the precipitation (both dry and wet) is not uniform in the world: it is especially high in the well industrialised regions and in their neigbourhood, according to the wind direction. UK, FRG, GDR and Poland are the most polluted countries in Europe. Hungary lies in a medium polluted area. The pH of the rain in Hungary changes from west to east from 4.5 to 5.5. The Hungarian part of the international network for measuring the chemical composition and acidity of the precipitates has been organized by the Institute for Atmospheric Physics. It consists of 10 stations with monthly sampling hy means of wet-only collectors. 2 station do also daily sampling. The schools can contribute to this work supplying some additional information:

1. The sampling can be done in a big number of stations so a higher spatial resolution of the precipitation can be achieved.
2. Daily wet-only sampling can be done in each school station.
3. The samples can be measured immediately after the rainfall so unwanted neutralisation cannot change the results.

School networks operate already e.g. in USA, FRG. In Hungary a preliminary study of acid rain was performed in the grammar school of Sárospatak detecting short time changes in pH values. Our goal is now the organisation of an acid rain monitoring network of schools. The acidity of the rain is expressed in pH units. Because of the atmospheric CO_2 the neutral point of the precipitations is $pH=5.6$. The standard method of determining the pH is by glass electrode, which is, however, too expensive and complicated for the school's everyday use. The so-called non-bleeding indicator paper is suitable for acid rain test since it is cheap, easy to handle and needs only small volume of collected rain water ($5\ cm^3$). We tested non-bleeding indicators papers graduated in 0.2-0.3 pH units by comparing the colorimetric method with glass electrode measurements using standard buffer solutions. The time necessary to reach the equilibrium in the practically non-buffered rain water was found to be about 5 to 15 hours. Computer program serves for data handling and for visual demonstration of spatial and time distribution.

We measured the pH of rain water for half a year in Budapest daily (wet-only sampling, immediate pH measurements, at least 3 parallel readings) resulting in a time dependence curve of the pH in the centre of the metropolis with a mean value of about $pH=4.5$. In the course of organizing the school's network of acid rain monitoring about 40 schools expressed their willingness to participate the long period project.

ENVIRONMENTAL PROBLEMS IN PUBLIC EDUCATION

Helmut Mikelskis
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I. Preliminary Remarks: looking back

Eight years ago I gave a lecture here at this very place with my colleague Roland Lauterbach on the theme of "Teaching the Issue of Nuclear Power". Those of you who were there may still remember the controversial dialogue about the pros and cons of the nuclear power stations. May I refer the others to the GIPEP-proceedings.

During the lecture we presented our teaching unit on "Energy Supply by Nuclear Power Stations", first published in 1976 and reprinted in 1980 by Klett-Verlag, Stuttgart (Fig. 1). It is still used for teaching purposes. Our problem-orientated view of teaching physics, which we relate to society, has since received wide recognition in the FRG, despite the fact that it was still very controversial when the book was published 13 years ago. This approach has since influenced syllabuses and text books.

II. Aspects of the controversial issue "Nuclear Power", which is of great importance and public interest.

The problems of nuclear power in the FRG can be seen as follows:

1) There are 20 nuclear power stations (with totaly 22 000 MW) in operation (this accounts for about 25% of electricity produced). But no further power stations are being built or planned.

Mikelskis/Lauterbach

Energy supply by nuclear power stations

IPN Physics Curriculum grades 5-10

Klett: Stuttgart 1976 (2. ed. 1980)

1 Nuclear power stations - the pros and cons

2 Which aspects does the topic "Energy supply by nuclear power stations" have?

A. Atomic and nuclear physics

3 What is an atom?
4 What are isotopes?
5 What is radioactivity?
6 How can one measure radioactivity?
7 How can one illustrate radioactive decay?
8 What happens during nuclear fission?

B. Technology of nuclear power stations

9 How are thermal power stations constructed?
10 How does nuclear power station function?
11 What types of reactors exist?

C. Dangers arising from the use of nuclear energy

12 What are the effects of waste heat on the environment?
13 What are the dangers of radioactivity to mankind?
14 What can be done with atomic waste?

D. Economic and political contexts

15 What are the relations between the nuclear energy, economic growth, and standard of living?
16 Who participates in, is concerned with the planning, financing, constructing, and running of nuclear power stations?
17 Can the supply of nuclear fuel be guaranteed?

E. History and future: Alternatives to nuclear energy

18 Which historical events are related to the development of nuclear energy use?
19 Are there alternatives to nuclear power stations?
20 Nuclear energy - for or against?

Fig. 1

2) The fast breeder reactor in Kalkar and the gas-cooled high-temperature-reactor in Uentrop-Schmehausen have cost till now 11 milliards of DM, but are not to be used.

3) The construction of a national reprocessing plant in Wackersdorf has been abandonned. 3 milliards of DM have already been invested in this project. But electricity industries, not our government, decided to make reprocessing in France and Great Britain. They flee the costs and the anti-nuclear-power-movement in our country. A final solution to the problem of the storage of nuclear waste in saltmine near Gorleben has not yet been found.

4) The accident in Harrisburg in spring 1979 and the catastrophe in Chernobyl seven years later in the spring of 1986 (one wonders what awaits us in the spring of 1993, another seven years later) have changed public opinion in the FRG so that a majority is now opposed to nuclear power.

5) All of the political parties regard nuclear power as a temporary source of energy. Opinions range from "abandonning nuclear power immediately", (The Greens) through "abandonning nuclear power as soon as possible, at the latest by 1998 (Socialist Party) to waiting until existing reactors have outlived their useful life (Conservatives).

Nuclear power is an important and complex social issue in our country. It should first be examined from various angles when considering how it should be taught (Fig. 2).

III. The Nuclear Issue : Nuclear Physics Education and Environmental Education.

The nuclear issue has long been treated as a part of nuclear physics for the purposes of teaching. This inevitably led to aspects of the subject being overlooked.

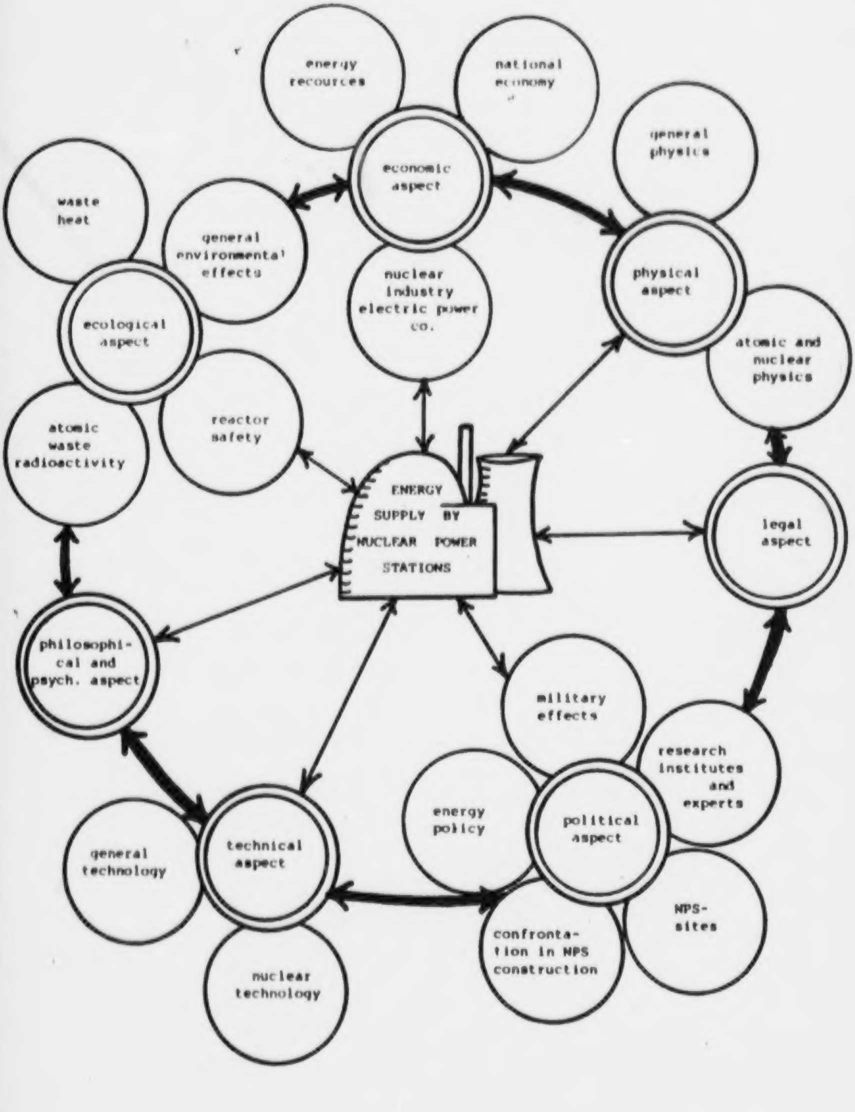
energy recources
national economy
general physics
economic aspect
waste heat
general environmental effects
physical aspect
nuclear industry electric power co.
ecological aspect
atomic and nuclear physics
atomic waste radioactivity
reactor safety
ENERGY SUPPLY BY NUCLEAR POWER STATIONS
legal aspect
philosophical and psych. aspect
military effects
research institutes and experts
energy policy
political aspect
general technology
technical aspect
NPS-sites
confrontation in NPS construction
nuclear technology

Fig. 2

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Let us start by asking the question: "How should public education, or schools which provide an all-round education approach the nuclear issue?" Should "Nuclear Education" be treated primarily as part of a general environmental education? This is the only way of ensuring an appropriate pedagogical treatment of the problem.

I should like to deal with seven elements of environmental education. They are based on a general critique of schools which goes beyond the themes of nuclear energy and the environment.

1. Environmental Education means learning by being concerned

Day to day education is all too often characterised by learning, revising and testing without the involvement of the learner. The daily avalanche of "prefabricated knowledge" and "fast information" which confronts us kills off any tendency to reflect or be astonished by something, and dissuades hesitant attempts to ask questions.

However real learning thrives on the unification of external stimuli and the inner world of the learner. If I am connected with something, I myself feel responsible for it; it concerns me.

As far as the environment is concerned, it is a sad fact that such stimuli are to be found on our doorsteps: polluted air and waterways, monotonous surroundings, nuclear power stations, not only Harrisburg and Chernobyl, but the plant nearby, toxic and radioactiv substances in our food, the countryside carved up for traffic, the proliferation of plastic, the barrack-like atmosphere of the schoolyard, the concrete monotony of school blocks, the technical nature of learning itself: exact, effective, yet cold and impoverished.

2. Environmental education involves understanding our current situation in its historical context.

Most young people at school today were not born when "The Limits to Growth" appeared and when Sunday driving was banned during the oil crisis of the early 1970s. Viewing things in their historical context allows us to relate them to a broader context. The present is the product of past events. Present circumstances can in turn be changed. We have moved from a static to a dynamic view of the world.

Knowing that people could once swim in the Rhine or the Danube raises our hopes that it will be possible again in the future, but it also causes us to fear that swimming in the Baltic or in the Mediterranean, which we now take for granted, could also come to an end in the not too distant future, and the developments which can be observed in these seas show that such fears are not unfounded. Contemplating the past also enables us to contemplate the future.

The history of the atomic energy explains really a lot of our problems today.

3. Environmental education involves developing the senses and schooling perceptions

We must once more learn to make more time for our own perceptions. The senses may be seen as a sort of anchor which ties us to the present. The physicist CAPRA describes our current crisis as a "crisis of perception". We endeavour in vain to apply the concept of a long outmoded mechanistic view of the world to a reality which simply does not allow itself to be understood by using this framework of ideas. CAPRA calls for an ecological view.

Where almost all environmental problems are concerned the lack of sensory perception is proving to have particularly dire consequences. In the age of databases, computer terminals and cable link-ups; in a "media age"which inundates us with information, there is an ever increasing danger that we shall lose our own sensuous experience of nature.

The problem of the radioactivity is, that we have no senses for it. And the big scale of modern energy technology is fare away from our daily perceptions. Nobody can have a feeling of 1300 MW. A windmill is much nearer to human imaginative faculty.

4. Environmental education means learning holistically

According to Morris BERMAN, holistic cognition is the original and ecological way of perceiving nature. Modern analytical science has tried to eradicate holism, but the successes achieved, for instance in the development of technology, were dearly bought.

The compartmentalisation of life has led to alienation in all areas. The custom of learning separate subjects in 45-minute blocks, is diametrically opposed to the holistic nature of our confrontation with environmental problems. System research and the concept of "networking" have been further developed in connection with ecological issues. However, the integration of analytical and synthetic processes makes great demands on the teacher because barriers set up by schools have to be overcome when organising interdisciplinary teaching for example.

Water must no longer be reduced to a mere chemical formula - H_2O. Water means swimming, the ocean, life, drink, rain, the water cycle, and much more. Water challenges: in science, technology, society, poetry, art, and philosophy.

5. Environmental education means encouraging pupils to form their own judgements

The reason for encouraging pupils to exercise their own powers of judgement is not merely to enable them to acquire the knowledge necessary for making a judgement, but to enable pupils to distinguish between important arguments and that which is irrelevant, and between correct and incorrect statements in a debate on the pros and cons of a nuclear power plant, for example. It is important that pupils should be able to acquire knowledge for themselves and have the capacity to reach a well-founded conclusion.The conclusion will of course always be a provisional

Kress/Mikelskis/Müller-Arnke/Reichenbach

ENERGY - Renewable Energie Resources and Alternative Energy Technologies

A Textbook for students of grades 10-13 (in German)
Diesterweg/Sauerländer: Aarau/Berlin/Frankf./München/Salzb.1984

1. Energy Supply in the FRG

1.1. Energy Consumption in the FRG
1.2. Thermal Power Stations
1.3. Nuclear Power Stations

2. The Sun as Energy Source

2.1. The Power of Solar Radiation
2.2. Energy Production by Nuclear Fusion
2.3. Radiation of Solar Energy
2.4. Absorption of Solar Radiation

3. Alternative Production of Heat

3.1. Solar Collectors
3.2. Heat Pumps
3.3. Active and Passive Solar Energy Use
3.4. Bioenergy
3.5. Geothermal Energy
3.6. Elementary Concepts of Thermodynamics

4. Alternative Production of Electrical Energy

4.1. Windpower Stations
4.2. Photovoltaic - Solar Cells
4.3. Energy Supply by Hydropower
4.4. Fuel Cells
4.5. Energy Source Hydrogen
4.6. Basic Physics of the Generator

5. Possibilities of Saving Energy

5.1. Survey of Energy Saving Possibilities
5.2. Energy Saving in Industry
5.3. Energy Saving at Home
5.4. Energy Saving in Transportation
5.5. Energy Saving and Nutrition

6. Energy Economy and Policy in the FRG

6.1. Elements of Alternative Energy Policy
6.2. Effects of the Energy-Economy-Law
6.3. Energy Research and Development

Fig. 4

assesment pending new knowledge, but it should in principle be taken as seriously as the judgement of the so-called expert.

Acquiring the power of judgement may be a high goal, but ecological education which stops short of this aim is meaningless.

6. Environmental education means learning to act

The divide between judgement and reality, that dialectic between what "should be" and what "is" must bear fruit. Action must grow out of experience and cognition.

Apart from the internal field of action within education, ecological learning should always include outside action as a yardstick to reality with all its opportunities and limitations; only then can it take on its necessary social and political dimensions. If we wish to surmount the ecological crisis, if we wish to survive, we must act, and acting must be learnt, more so than much of what we find in syllabi today. We do not need young people who passively watch what is happening in the world, we need active young people!

The links between knowledge, experience and action are very important for the learning process.

7. Environmental education means being guided by an imaginative view of the future

When it comes down to it, the whole ecological movement is an expression of care for our future. Concern for ecology means concern for the future. For the first time in the history of mankind it is no longer exclusively a question of means but also of ends in terms of our future. Education as such is always directed at the future.

However it is extremely difficult to prepare for unknown and often unforeseen situations. Anticipatory learning is theoretical-conceptual learning as well as creative discovery learning, and it requires the ability to think associatively and imaginatively about the future.

7 elements of environmental education 7 aspects of the nuclear power issue	1. affectedness	2. historical context	3. senses	4. holistically	5. power of judgement	6. action	7. future
A physical	Spintharicop	Otto Hahn					fusion
B technical	fascination	U-bomb	Mega-technology			measurement of radio.	atomic waste
C ecological	chernobyl		environment	ONE world	radioactivity	Greenpeace	long term effects
D philosophical	fear		feelings	What is human!		Think!	
E legal					tribunal		
F political		Manhat. project		interrelations	pros and cons	Anti Nuke Movem.	third world
G economic	poverty				profit and Loss	energy saving	

Fig. 3

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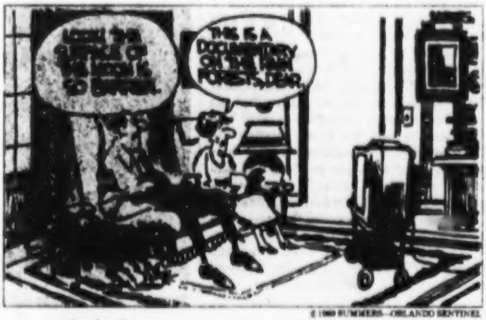
The forward-looking nature of ecological education, and indeed that of education as a whole, is more than a matter of form, it is the thorn in the side of the ritualised science of results, the efficiently organised world of prefabricated learning products which involve repeating what has been done before. Above all, being forward-looking means accepting the freedom of education.

IV. Teaching Nuclear Power in the framework of Environmental Education.

I have described seven aspects of the issue of nuclear power. It should be taught within the framework of the seven elements of environmental education. This is intended as a sort of viewfinder which should make it possible to make didactical decisions as to how the nuclear issue can be incorporated into public education (Fig. 3).

Books for lessons in physics acording to this interdisciplinary approach may look perhaps like the "Energy book" in fig. 4. But this is no politics book, no economy book, no environmetal education book - may be it is all! But who cares about this?


THIS IS A DOCUMENTARY ON THE RAIN FORESTS, DEAR.

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THE BUSINESS OF FUTURE

E. Leonard Jossem, president of International Commission on Physics Education
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Columbus OH 43210-1106, USA

Life is full of risks. George Marx took a very large one when he asked me to speak at the end of our conference and to try to capture its spirit -- to try, in some way, to say what the conference was all about. For such a large conference with such a large variety of topics being discussed that seems to me to be an exceedingly difficult, if not impossible, job. All I can hope to do in the time available is to give you some very personal impressions and opinions and to hope that at least some of them will find resonances with your own.

If one is obliged to characterize the conference in a single short phrase, perhaps the most obvious one would be that it has been concerned with planing for the future. It has been said that the business of mankind is planning for the future. That is never an easy job, both because, "*The future is no longer what it used to be.*"(1) and because "*The trouble with the future is that it usually arrives before we are ready for it.*"(2)

Planing, as I see it, means trying to foresee the consequences of the actions we take in order to change the future in ways that seem desirable to us. The fact that we *intend* to change the future has the strong ethical implication that we should act responsibly. We need to be prepared to take responsibility for the consequences of our actions. We all know from experience that when decisions are made and actions are taken in ignorance, or blindness, or with attention only to immediate results, the consequences can be disastrous. (See Figure 1)

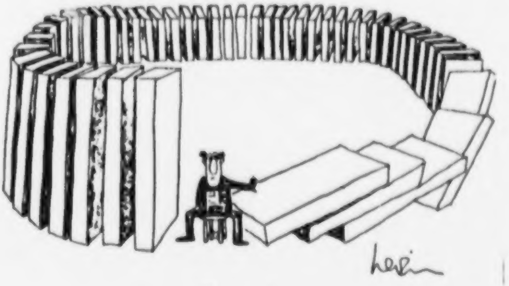

Figure 1

The gentleman in this cartoon is obviously unaware of the nature of his environment. In his ignorance of the world around him he creates a disaster for himself. He reminds us that, "*If you think education is expensive, try ignorance.*"(3)

It is interesting to see what others have had to say about the future. For example:

"*.. At the present moment a discussion is raging as to the future of civilization in the novel circumstances of rapid scientific and technological advance. ..... Modern science has imposed on humanity the necessity for wandering. Its progressive thought and its progressive technology make the transition through time, from generation to generation a true migration into uncharted seas of adventure. The very benefit of wandering is that it is dangerous and needs skill to avert evils. We must expect, therefore, that the future will disclose dangers. It is the business of the future to be dangerous, and it is among the merits of science that it equips the future for its duties.*"(4)

These words by Alfred North Whitehead, the mathematician and philosopher (1861 - 1947), come from his Lowell Lectures at Harvard University in 1925. A contemporary of his, H.G. Wells (1866 - 1946), noted many years ago that "*Human history becomes more and more a race between education and catastrophe.*"(5) If anything, the race is even closer today than it was in his time.

What does all this say to us as teachers? Perhaps that as teachers we have a responsibility to help our students to learn to face the dangers of the future and to help them to learn to plan wisely. We need to help them to understand clearly the problems with which we and they are faced, and to show them how to do careful and responsible estimates of risks -- and of the uncertainties in those estimates -- so that they do not just stumble blindly into the future.

In Whitehead's remarks he talks about wandering and about uncharted seas of adventure. Recently mankind has been wandering past the planets Jupiter, Saturn and Neptune, on the Voyager spacecraft and has seen many new and unexpected views of the solar system. Now Voyager is taking us out of the solar syatem on new adventures in the truly uncharted seas of space.

This brings me to what I would like to talk about next. It also has to do with intellectual and physical adventure.

On 28 January 1986, in full view of a world-wide television audience, two women and five men, the crew of the Space Shuttle Challenger, met their deaths.

There was, of course, an investigation of the causes of this tragedy, and a Presidential Commission issued a report in five large volumes.(6) I would like to suggest that the Challenger disaster has a special significance for us as physics teachers for two reasons. The first is that the analysis of the causes of the disaster involve simple ideas from classical mechanics which should be easily accessible to most students. The second reason is that there was something unique about the investigation and the report. The unique factor was the presence on the Presidential Commission of someone whose name is well known to you all: Richard P. Feynman. As he always did, Feynman had his own ideas about how an investigation should be conducted and what were the important questions to try to answer. He wrote a special Appendix to the report entitled "Personal Observations on Reliability of Shuttle" (Appendix F in Volume II). I would like to read you the first paragraph just to give you a bit of the flavor. It is pure Feynman.

"It appears that there are enormous differences of opinion as to the probability of a failure with loss of vehicle and of human life. The estimates range from roughly 1 in 100 to 1 in 100,000. The higher figures come from working engineers, and the very low figures come from management. What are the causes and consequences of this lack of agreement? Since 1 part in 100,000 would imply that one could put a shuttle up each day for 300 years expecting to lose only one, we could more properly ask "What is the cause of management's fantastic faith in the machinery?"

Feynman also gave an account of his experiences on the Presidential Commission in his book "*What Do You Care What Other People Think?*"(7) If you have not yet had the opportunity to read it I recommend it to you and your students very highly. It is well worth reading for Feynman's insights into how risk estimates are made and how strongly human factors can enter into them and into our decisions for actions.

References:
1. Attributed to Paul Valery
2. Attributed to A.H. Glasgow
3. Attributed to Derek Bok
4. Alfred North Whitehead in *Science and the Modern World*
   The Lowell Lectures, 1925, Chapter XIII, Requisites for Social Progress
5. Herbert George Wells in *The Outline of History*, Chapter 40 (1951 Edition)
6. Report of the Presidential Commission on the Space Shuttle Challenger Accident
   Washington, D.C. June 6, 1986
7. Richard P. Feynman in *What Do You Care What Other People Think?*
   W.W. Norton & Co. New York, 1988
   Part 2 of the book contains both Appendix F of the Report of the Presidential Commission and Feynman's personal description of the process of the investigation. Another version of Feynman's description appeared in Physics Today Vol. 41, No.2 February 1988, pp 26-37 under the title "An Outsiders Inside View of the Challenger Inquiry"

Future is uncertain. Eat dessert at first!

Leonard Jossem
chairman of I.C.P.E.

WORKSHOPS

A) ALERNATIVE CULTURES - ALTERNATIVE CURRICULA

The task was to study national curricula, to discuss student achievements, etc. from the point of view of differing cultural and social background. That is the reason why E. Gecső (Budapest) gave some information about SISS (Second International Science Study, which was organized by the International Association for the Evaluation of Educational Achievements in 1983) and he showed a lot of data about

- structure of science instruction in each Country,
- patterns of science teaching,
- percentage of an age group in school,
- selected characteristics of schools, teachers, students, etc.
- national average scores on the Science Tests in 20 participating countries. – J. Wendt (Berlin) recited the results of the 19. International Physics Olympiads (Bad Ischl, Austria, 1988). – There was an electric atmosphere while discussing the concept of curriculum under the chairmanship of J. Barojas Weber (Mexico). We did not come to final conclusion about it, but everybody agreed that the concept of curriculum involves much more than a statement of content. The science curriculum is considered to have process dimension as well. So each participant of the workshop gave a short report about their country and the national educational system. – In addition to the formal science curriculum of a school (or country) there is a hidden curriculum, the effect of which depends on the way how the school is managed and on the inter-personal relationship between students and teachers. Since the hidden curriculum is not specified, it is not amenable to analysis in the same way that the formal curriculum can be analyzed.

(*Ervin Gecső*)

B) STATISTICS: INFORMATION OR MANIPULATION?

Pick up a newspaper and encircle every item in which mathematics in required for its understanding or interpretation. Do you find equations or trigonometry? Instead you will find charts, graphs and words such as "average", "trend", "correlation", "unlikely", "chance" and "risk". You will see them on the sport pages, financial pages, in the weather report, in political opinion poll. Why do we find so many uses of statistics in the newspapers? Many of the decisions we make are based upon incomplete or uncertain data, many of our choices contain a certain risk of adverse effect. We collectively make decisions about the choice of energy for electricity generation with their respective risks of atomic waste disposal and acid rain from burning coal; of speed limits on highways; of residuals of pesticides and chemical additives in food; of maximum allowable adverse side-effects of medicines. We must be able to balance fear and opportunity by understanding the risks of alternatives. The Workshop discussed questions like how to react to the following sentence: "In the U.S.A. about 50 000 people die in car accidents each year, totalling one million deaths in two decades. Why worrying about nuclear reactor accidents."?

(***Edward Jacobsen***)

C) ACID RAIN MONITORING

School networks for environmental monitoring are already active in some countries (e.g. USA, FRG). Preliminary study of acid rain in Hungary was performed by children in the grammar school of Sárospatak, observing short time changes in pH values. Our main goal is now the organization of an acid rain monitoring network for Hungarian secondary schools by using simple measuring technique. - The acidity of the rain can be expressed in pH units. Because of the atmospheric CO_2 the neutral point of the precipitation is $pH=5.6$. The standard method of determining the pH is by glass electrode. This is, however, too expensive and complicated for the school's everyday use. We have found that the so-called non-bleeding indicator paper is suitable for acid rain test: it is cheap, easy to handle and needs only small volume of collected rain water ($5\ cm^3$). We tested non-bleeding indicators papers (graduated in 0.2-0.3 pH units) by comparing this colorimetric method with glass electrode measurements using standard buffer solutions, rain water, natural and distilled waters. The time necessary to reach the equilibrium in the practically non-buffered rain water was found to be about 5 to 15 hours. We also developed a computer program for data handling and visual demonstration of spatial and time distribution of the pH of the rain water. - We carried out a half years test series in Budapest with daily, wet-only sampling and immediate pH measurement resulting in the centre of the city in a mean value $pH=4.5$. So far 40 Hungarian schools expressed their willingness to participate the long period project.

(Ildikó Hobinka)

D) RADIOACTIVE FALLOUT MONITORING

In June 1987 and May 1988 the Institute of Physics (London) financed two English national surveys of background alpha radioactivity. 170 schools in 1987 acted as pilot sampling points to measure alpha activity and radon on the surface if the soil. In 1988, 750 schools participated in measuring radon and alpha activity at a depth of 80 cm below the surface of the soil. (see Camplin's and Henshaw's paper in this proceedings). The soil detector was simply a piece of track-recording polymer derived from allyl diglycol carbonate (TASTRAK, commercially C39), this was simply pushed into the soil.The radon detector was made from a 15mm·15mm square piece of TASTRAK which was hold flat in the bottom of a yoghurt pot by a piece of Blu-tac; and the mouth of the yoghurt pot was completely covered with a singe layer of clingfilm. The radon diffuses through this film. The subsequent alpha decays produce defects in the polymer. After two weeks of exposure time, schools returned the exposed pieces to Bristol University for etch processing, and then they were sent to Partway School for track analysis by microscope.The interim results of the 1988 survey suggest that,at 80mm below the surface, the average alpha activity is about 1000 Bq/kg and an average radon level of about 500 Bq/m^3. This result does bring to light that alpha activity is an important contribution to background radiation levels. Worksheets on these experiments were available for use at the workshop. The use of TASTRAK in school is a good way in educating pupils about radon and alpha radiation in the environment. We hope that many teachers and pupils will be involved in these measurements over the coming years.

(C.C. Camplin)

E) RADON MONITORING

This Workshop introduced some possibilities of students' activities in radon monitoring. We focused our attention to short observations. From pedagogical point of view some of the participants preferred to obtain immediate results in schools instead of months-long observations. (Concerning radon monitoring by Trastrak,see Workshop D.) – Students of three Hungarian high schools (József Attila Grammar School, Budapest; Lehel Vezér Gammar School, Jászberény; Lóczy Lajos Grammar School, Balatonfüred) introduced the radon monitoring method by a simple Geiger counter. The participants collected the sample from the air (dust and small droplets) with the help of a vacuum cleaner by putting 6 layers of medical gauze to the end of the tube of the vacuum cleaner and operating it for 30 minutes. The students presented their results: how they found two rooms close to each other in their school with very different radon contamination. (One of the room shows only the descendents of ^{222}Rn while the other room contains also the ^{220}Rn – both of the rooms showing relatively high activity.) The students reported their two long duration observations when they took samples every hour during a four days and an eight days period respectively. Correlation were discovered between the measured activities and the weather conditions. But all the students agreed that they have no data enough. A country wide School Network on Radon Monitoring is launched in Hungary in 1989 to get more data. – László Korecz (Eötvös University) introduced a very simple method to measure the radon in the air. He closed an electrometer (widely used in schools) very well after an air sample was taken. Giving charge to the electrometer one can observe the discharging versus time. The slow discharging is caused by the ion pairs produced by the decays of the Radon family. – Lennart Samuelsson (Linkoping University, Sweden)introduced the electrostatic collection method (see the Appendix of the paper L. Samuelsson in this Proceeding). It is very easy to handle! – As control we asked Gabor Szendrő, the representative of the Gamma Data GmBh (Sweden) to introduce the elegant automatic equipment (based on ionization chamber) which collected radon itself during the Workshop in the room and gave the activity of 1 m^3 air almost immediately. (It was 25 Bq/m^3.)

(*Esther Tóth*)

F) TEACHING ALTERNATIVES FOR ENERGY

In spite of having a few interesting reports of energy-teaching procedures and/or curricula and their evaluation, (see the papers of Priest-Rauckhorst, van der Walk, Castro) the discussion mainly followed a remark of the chairman that some effort must be made to clarify a few fundamental ideas and their interrelations in the minds of the physics teachers themselves. The discussion made it crystal clear that this is an urgent need, which is a pre-condition for the consistent and successful teaching of "energy" at school. Even the excellent group of participant of our Workshop might benefit of a well-prepared systematic discussion of these issues.

(*Yehuda Shadmi*)

G) RISK PERCEPTION IN SCHOOLS

As a specific example of risk assessment, the participants discussed the risks of using electric utensils, for example handling of a hand-drier in the bathroom. It was shown that even in such cases awareness is important in conduct. (A. Pflug, Vienna.) – A questionnaire, related to the radioactive pollution in Goiania,was discussed in details. It was demonstrated that ignorance,lack of information and lack of education could cause several accidents. (S. Barros, Rio do Janeiro.) – Television programmes often play down the risk of working at nuclear power plants. (J. Solomon, Oxford, see also elsewhere in this volume.) – The awareness of the risk involved by the utilization of atomic energy is very weak even at science students. It was shown how the Physics Department at the University of Extremadura in Spain tries to set this problem right. (F. Cuadros.)

(*Imre Légrádi*)

H) STUDENTS'S CONCEPTS AND CONCERNS

P.L. Lijnse (Utrecht) reported on research concerning pupils' notions of radioactivity in the context of nuclear energy: after studying media reports of the Chernobyl accident and after consulting radiation experts about the typical lay ideas he investigated the pupils' concepts about Chernobyl. They conducted a series of interviews with 16 year old pupils before and after having learned about radioactivity. One of the main conclusions is, that lay reasoning about radioactivity is very persistent and widespread. Physics teaching has to offer a more rational risk assessment. – There was a colorful report, illustrated by a number of slides, given by J. Fitzgibbons (USA), chairman of the Workshop. The topic was "The New York State Student Energy Competition". This annual event for secondary students is designed to arouse their interest in the energy problems of the state, to let them develop innovative solutions to these problems, to spark students interest in energy development. It was not left without mentioning that most of the winners attended selected schools such as the Bronx High School of Science. – Ana Csillag (Toronto) talked about teaching the topics of this conference in Toronto. In the break we saw a very extensive "private" exhibition of physics books brought by Ana Csillag. – After the break there was a discussion related to teaching about values which addressed the following questions: the controversial risk-related issues in the physics curriculum; the teacher's responsibility for enabling the students to make decisions; the connection between physics and sociology.

(*Dorothy Sebestyén*)

J) THERMODYNAMIC LIMIT ON ENERGY SAVING

Since more than 10 years, at the University of Karlsruhe a physics course for Juniour High School is under development. The project is now in its final phase. The course is actually being tested by 28 teachers with more than [illegible] pupils. In this course the extensive or "substance-like" quantities like energy E, momentum p,electric charge Q, entropy S and amount of substance n, as well as the corresponding currents play a dominant role. We take profit of the fact, that a far-reaching analogy between various physical domains can be established on the basis of these quantities. This analogy shows itself, amongst other things, in the equations, which relate the energy current with the currents of the other substance-like quantities. – We make some very short remarks about the thermodynamics part of the course. Considering the above-mentioned analogy one can state that: *Thermodynamics without entropy and without entropy currents is like electricity without electric charge and without electric currents or like mechanics without momentum and without force.* Thus we operate with entropy from the very beginning of thermodynamics. We use none of the Legendre transforms $H(S, p, n)$, $F(T, p, n)$ of the energy $E(S, V, n)$ since they don't obey a continuity equation and it is thus very difficult to form an intuitive idea about them. The popularity of these quantities is due to the traditional phobia against entropy. – It can be stated that the correspondence between the colloquial meaning of "heat" and the physical quantity entropy is much better than between the colloquial "heat" and the process quantity heat of the physicist. One can say that the correspondence between the every-day concept of heat and the quantity of entropy is almost perfect. There are very few other examples of such a perfect relationship between a concept of every-day life and physical science. It follows that entropy can be taught in a way that is appears as one of the simplest physical quantities, much simpler, for instance, than the other extensive quantities energy and electric charge. – We formulate the second principle of thermodynamics as follows: *Entropy can be produced but not destroyed.* In the course of our thermodynamics teaching we introduce four types of a generalized friction or resistance: mechanical friction; electric resistance; chemical resistance (a chemical reaction runs against a reaction resistance); thermal resistance (entropy flows through a thermal resistance). In either of these cases entropy is produced. Every process with entropy production can, in principle, be replaced with a process without entropy production and which is as useful for us as the entropy producing process. We thus formulate: *Avoid entropy production.*– All the energy which is consumed for some human purposes is finally used to produce entropy according to *energy consumed = temperature x entropy produced.* Thus, our most important, inexhaustible energy source is avoiding entropy production. In more common, but somewhat pejorative terms, this is called energy saving.– The comments of Hanna Goldring (about the efficiency of heat engine compared e.g. to hydroelectric turbine) and Maria-Luisa Viglietta (about Carnot efficiency) complemented the program.

(*Friedrich Herrmann*)

K) SOLAR POWER AND WIND

Oved Kedem (Israel) presented a demonstrated lecture about his country's solar pond project. The solar pond is a salty lake with higher salt concentration at the bottom. The concentration-gradient prevents convection. The bottom layer heated by the solar radiation becomes much hotter than the top ones. (This phenomenon was discovered by Alexander von Kalecsinszky at the Medve Lake in Szovata, Hungary in 1901.) The temperature-difference can be used for electricity generation. Clearly, the system is able not only collect the solar energy but to store it as well. The overall efficiency is about 1%. The effect can be demonstrated in school. In an open –air experiment we found a few centigrade temperature-difference. – Atso Vironseppa (Finland) spoke about his country's electric windmill project. Windmills seem to be a good solution for electricity— need of small islands.

(*Géza Meszéna*)

L) NUCLEAR SPECTROSCOPY FOR SCHOOLS

This workshop dealt with the present status of the nuclear experimentation. The 22 participants agreed that this is the field where major differences occur between developed and developing countries. C. Davisson (USA) showed a really simple demonstration of thermoluminescence. Salt crystals previously irradiated with a very large dose were thrown on a hot plate. The luminescence could be clearly seen in a dimmed room. The problem with this experiment is to get the crystals irradiated. This needs cooperation of medical or nuclear institutions. – J. Turlo (PL) has shown a simple interface and a program for a small Sinclair ZX Spectrum, which enabled to count the pulses of a Geiger-Müller counter, and to perform statistical tests on the collected data. This is so simple that it can be fabricated by the teachers themselves. – In the last years the prices of computers have decreased more and more schools are equipped with computers even in the developing countries. It seemed to us, that the IBM-PC/XT/AT has become a standard, so most of the experiments should be interfaced to that machine. Although the IBM-PC itself is not conceived for interfacing experiments, and therefore several problems may occur, there are enough extension cards on the market to overcome this problem. The participants agreed, that beside the simple counting task also gamma-ray energy analysis would be desirable, what would enable the determination of the radioactive isotope occurring in the environment. This task needs however more complicated equipment and probably it cannot be done by home-made devices. Gábor Szendrő (GAMMADAT, Sweden) introduced an equipment consisting a NaI(Tl) scintillation crystal with high voltage power supply, an ADC converter, an interface card to fit in the IBM-PC/XT/AT and an appropriate software, which could take gamma spectra, and to monitor radon as well. – Prof. Shimizu used semiconductor photodiode instead of photomultiplier. This method has the advantage that the photodiode does not need high voltage and therefore it is more safe, it is easier to handle. Unfortunately the big photodiodes (at least 1 cm x 1 cm) needed for this purpose are quite expensive.–Because of the limited time the workshop could choose only some choice from the large menu of the possible nuclear experiments in schools. Many other important methods and ideas (solid state nuclear track detectors, films, demonstrations, simulations) were treated at other workshops.

(*Csaba Sükösd*)

M) FUTURE VOLTAGE

This workshop was centered around one computer software developed by Bert de Vries (University of Groningen, Holland). The purpose of the software is to provide an experimental tool for the user to check some idea [illegible] the energy supply in a certain country for the future. One of the biggest questions we are facing with nowadays is to tell what kind of a power plant to built in order to provide enough energy for the future, but spend as little money as possible. We also should think of pollution and risk: the best choice would be a plant with no pollution at all and with very low accident risk. The above mentioned parameters can be specified for different kinds of power plants in the computer code. It is possible to enter the set of existing plants for a specific country along with some general variables describing the current economical and industrial situation in the given country. The program will calculate the energy demand for the future while the user can make decisions about building new power plants. The program countinously calculates the available energy along with pollution and the risk of an accident. The aim is obvious: the user should provide enough energy for the future on the lowest possible price while keeping the pollution and risk very low. - The software comes with a detailed manual, so that it is relatively easy to learn how to control the program. Before running the game the user should set up the necessary data file for his country. With some experience (and available data) it can be done quickly.

(Zsolt Frei)

N) COMPUTER SIMULATIONS OF POWER AND RISK

The aim of this workshop was to present some computer codes related to the topics of the conference. - George Marx, Hungary, presented several softwares contained by a single diskette which are useful in education. The codes are simulating some basic effects of nuclear physics such as slowing down fast neutrons, controling neutron flux with absorbent rods, etc. There is an interesting program to simulate the greenhouse effect. After the input of fossile fuel consumption and population growth trends one can have a glimps of increasing temperature and rising see level with increasing carbon-dioxide concentration. Other programs are highly demonstrative as well. - Sándor Élő (Hungary) gave us a nice overview of a sophisticated computer software which simulates a reactor core of a real nuclear power plant. This code was developed at the Technical University of Budapest and used by utility companies. The software expects an experienced user with reactor physics background, so that it is not for in class use. - Zsolt Frei (Hungary) presented a simpler nuclear power plant simulator for IBM-PC which can be used for educational purposes but very much simpler than the previous one. - We enjoyed the simulation of raddioactive decay (P. Thomsen, Copenhagen) and the elaborated Solar Power Station code (A. Manabe, Japan).

(Zsolt Frei)

O) THE RISKS OF THE GAME OF SEX

Participants of this workshop played the game which indicates the different motivations and risks of girls and boys in sex. POMP AND CIRCUMSTANCE is an educational game. It has two major purposes: to provide information about the costs, discuss and think about their own contraceptive choices. Why a game? The traditional methods of sex education such as classroom lectures and reading assignments, have made little impact on rising teenage pregnancy rates. The gaming approach has several promising characteristics; most importantly it involves the player directly in the learning process. That is, the player is an active participant who makes decision in a simulation of the real-world context. Most teenagers are understandably reluctant to discuss their own sexual and contraceptive behavior within a teaching environment. For many, sexual matters are awkward topics. In the game, all rules, events and decisions are simulations, they are modelled from the real world. However, they are presented in an abstract form, so that players are not aware of the subject matter while negotiating and making decisions. Thus, they are free to develop gaming strategies without worrying about how they "should" behave or how their behaviour will be perceived by others. - The participating "couples" came from several countries and they were of different ages. They enjoyed very much the first part of the game, in which they tried to agree with each other in decisions. When the game was over, the parallels between the elements in the game and the "real world" were revealed and strategies of play and decisions made are discussed. The presence of the prominent human genetists, of Dr. Andrew Czeizel (Budapest) and Dr. Jane Evans (Winnipeg, Canada), who turned to become "professional sexologists", were very helpful in drawing the conclusion. Players could review which game strategies were most successful, they compared the rules of the game with the pressures, opportunities and consequences in the real world. It was very interesting, we founded at the "girl-players" a lot of "red-chips" (representing love and romance), at the "boy-players" a lot of "yellow-ships" (representing sexual gratification).

(*Kate Papp*)

P) VISITING THE LOCAL GRAMMAR SCHOOL

28 visitors from 18 countries met the director, teachers and pupils of the Lóczy Lajos Grammar School in the physics lecture-room. After the director's brief information on the history and character of the school, the guests were mostly interested in the number of lessons, in the text-books and curriculum. They had a look at the experimental instruments. - The guests asked the students - among others - about the time spent in learning languages and physics. (The students present could speak English, German or Russian.) The following conclusions can be drawn:

1. Too many lessons a week - especially when studying in special language classes.
2. The teachers's weekly load hours to be too high.
3. The subject-matter of the 4th form physics text-book too difficult, especially for pupils who want to specialize in foreign languages.
4. Too many pupils in one class (35-40).
5. Too little free time left for the pupils after the lessons and learning.
6. Not enough instruments; those available not up-to-date in certain fields.

(*George Vastagh*)

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